LECTURES

ON THE

STUDY OF CHEMISTRY

AND

DISCOURSES ON AGRICULTURE.

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LECTURES

ON THE

STUDY OF CHEMISTRY,

IN CONNEXION WITH

THE ATMOSPHERE, THE EARTH, AND THE OCEAN:

AND

Discourses on Agriculture;

WITH INTRODUCTIONS ON THE PRESENT STATE OF
THE WEST INDIES, AND ON THE AGRICULTURAL SOCIETIES
OF BARBADOS.

BY

JOHN DAVY, M.D. F.R.S., L. & E.
INSPECTOR GENERAL OF ARMY HOSPITALS;
HONORARY MEMBER OF
THE GENERAL AND OF THE DISTRICT AGRICULTURAL SOCIETIES OF
BARBADOS, ETC.

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LECTURES

ON THE

STUDY OF CHEMISTRY.

DEDICATION.

TO

THE MANAGERS OF THE

"REID SCHOOL OF PRACTICAL CHEMISTRY"

OF BARBADOS.

GENTLEMEN,

I DO not know to whom I can dedicate these few lectures with so much propriety as to you; for at your solicitation they were prepared, with your aid they were given, and at your request they are now published.

In each particular I have been gratified. I have felt, too, a distinction conferred on me, in having been so permitted to come forward in the way of usefulness.

With the hope that the zeal which you have

already shown in the aid given by you towards the founding of the "Reid School of Practical Chemistry" will be continued without abatement, and be amply rewarded by success, I beg to subscribe myself,

GENTLEMEN,

With much respect and esteem,

Your obedient, humble Servant,

JOHN DAVY.

Lesketh How, near Ambleside,
January 5. 1849.

INTRODUCTION.

Of late years, owing, no doubt, to a variety of circumstances, and especially since the great measure of slave emancipation has been effected, a change has been taking place in the West Indies, in the state of its society, its feelings and wants, which is now becoming conspicuous, and can hardly fail to be so in its lasting effects.

1st, I believe it may be stated confidently that manners have improved, that the tone of society is more moral, religious, and correct, and that the dissipation, before too common, and the extravagant living, and a tolerated licentiousness, are now little more than matters of record.

2dly, That a strong disposition has been shown, and no small exertions made, to improve agriculture, as indicated by the establishment of agricultural societies, of which no less than four at present exist in Barbados, viz. three district ones, and one general; and, further, by the introduction of implements in husbandry — the plough

(the first toast at the dinners of the agricultural societies), the horse-hoe, and other economical substitutes for the hoe, not long ago the chief, and, indeed, almost the only instrument employed in the olden time of slavery.

3dly, That a like disposition has been shown, though more recently, and like efforts made, though in a more limited way, to improve the making of sugar, (the only manufacturing process with the associated one of rum, of late years attempted in the colonies,) as indicated by the introduction of costly inventions for the purpose, such as the vacuum-pan, and that commonly called Gadesden's pan,—the experiments that so many planters are making with the same intent, and the attention so generally given to the subject.

4thly, That a want of exact scientific knowledge has begun to be felt, with a desire for its introduction and diffusion — a want founded on the enlightened belief that no great advance can be made in the state of agriculture in the West Indies without the aid of agricultural chemistry, or any considerable improvement made in the manufacture of sugar, without a knowledge of the chemical principles concerned, a knowledge the possession of which has been found so eminently useful at home in the refining of sugar, and in France and Germany in the extraction of sugar

from the beet-root. Proof of this is afforded in the publication of the "Agricultural Reporter," commenced now nearly four years ago, and continued with increasing zeal and ability, the motto of which is "Science with Practice," and the professed aim of which is their union; in the publication of many tracts on the culture of the cane and the making of sugar in the several colonies, containing much useful information; and further, and more recently, in the efforts made, and which may be described as in progress, to form a school of practical chemistry.

On this attempt it is incumbent on me to offer a few particulars. The want referred to, especially of exact elementary knowledge in chemistry, being brought under the consideration of the late Governor-General of the Windward Islands, Lieut.-Colonel Reid, he, sensible of the need, and always anxious to give larger and more improved means of instruction to the people, took up the matter warmly, had a subscription paper prepared, and a provisional committee formed, and was not only a most liberal contributor in aid of raising funds for the purpose of laying a foundation, but likewise published, at his own expense, and widely circulated, gratuitously, a little work, entitled "Rudimentary Chemistry," written by Professor Fownes *, whilst passing some months in Bar-

* Since the above was written, I regret to have seen announced the death of this amiable and talented man.

bados as an invalid, and which, for simplicity, clearness, exactness, and nice adaptation to the end in view, is not unworthy of the pen of its able and estimable author. Another aid had been contemplated by Professor Fownes, which, though not carried into effect, it is to be regretted, ought to be noticed, viz. the opening of the school by a short course of lectures on the elements of chemistry. Impaired as his health was at the time, and requiring rest and relaxation, this, in his zeal, he would have given, had the apparatus arrived from England which had been ordered, and was then daily expected.

After the receipt of the apparatus, procured by means of the original subscription, the first measure taken by the Provisional Committee was to make a report to the body of subscribers, and to propose a plan for the formation of the school, under the name of the "Reid School of Practical Chemistry," in honour of its excellent founder, and distinctive of its objects.

That proposed plan, with the name, was unanimously approved and adopted at a meeting held on the 24th of June, 1848, following one of the General Agricultural Society, at which his Excellency Governor Reid presided. A part of the plan

It took place on the 31st of January, when in his 33d year, from pulmonary consumption, the disease he was labouring under when he visited the West Indies.

was, that preparatory to the opening of the school for practical teaching, courses of lectures should be given of a popular kind, by such gentlemen of the Board of Managers as might be willing to perform the duty gratuitously, to be opened at a cheap rate of admission, without exclusion of any respectable person, with the hope of exciting a taste for chemistry, and spreading more widely an interest in and a desire to contribute to the support of the institution; it being resolved that the funds raised by the lectures should be appropriated solely to the uses of the school.

The gentleman who took the lead as a lecturer was a member of Council, the Hon. Grant Thomas. His introductory lecture was delivered on the 2nd of August, in Harrison's school-room, a school endowed for the education of the youth of Barbados, by the gentleman whose name it bears, the master of which, Mr. Hollingsed, had obligingly allowed a room in his house to be used as a temporary laboratory and place of deposit for the apparatus. The audience was a crowded one, and of a very mixed kind, and not uncharacteristic of the occasion. The boys of the school, in number hardly less than sixty, who had previously had some useful instruction in the elements, gratuitously given by Mr. Drumm, an intelligent druggist of Bridgetown, formed no inconsiderable part of it. The highest dignitaries

of the island were present,—his Excellency the Governor-General, the Bishop of Barbados, Lieut.-General Berkeley, commanding the troops in the Windward and Leeward Islands, the Chief Justice, a considerable number of the most respectable gentlemen of Barbados, and, to grace the whole, there was a large attendance of ladies. The lecture was well received, as it deserved to be, for it was excellent of its kind. It was followed by others by the same gentleman, not inferior to the first, to the extent of eight, and which, it may be mentioned with confidence, were as acceptable.

The four lectures, which are now published, were delivered between Mr. Thomas's 4th and 5th lectures, an interruption he obligingly allowed, in consequence of the author being then in almost daily expectation of his recall to England, his period of service in the West Indies having expired.

Such is a brief sketch of the origin of the "Reid School of Practical Chemistry," a school which, if supported, as I trust it will be, may from such a small beginning become an important institution, and be the means of imparting not only knowledge of the most useful kind to the planter, considered as an agriculturist and a manufacturer, but also a knowledge which cannot fail to be beneficial to society generally, and that

in various ways, as is attempted to be pointed out in the following introductory lecture.

In its early feeble state, this school seems to be particularly deserving of the attention of the Home Government. Without aid of a pecuniary kind from home, its efficiency for a long time must be inconsiderable; indeed, without such aid, it is not improbable that it will languish, and after a few years of struggle come to an end. If timely assisted by a grant, sufficient to procure a more suitable apparatus, and to pay an able teacher from England, then it might rise into instant usefulness, and be of incalculable value for the objects for which it is intended.

The present time is one of struggle between free labour and slave labour; one of an eventful nature, in which the welfare of mankind is concerned in no ordinary degree. The home market is now opened to slave-grown sugar; and shortly the duties will be the same on such sugar as on that produced by free labour.

To ensure successful competition on the part of the planter employing free labour—that success which should make it the interest of the slave owner to emancipate his labourers, it is most desirable, perhaps it is absolutely necessary, that every advantage should be given to the planters in our colonies, compatible with the good of the mother country, or rather, it should be maintained,

with the good of the empire at large; and every encouragement afforded to the colonies to effect improvements. It is not sufficient to assure the slave owners that the security of person and property, the mental comfort, the quiet conscience resulting from emancipation, are felt to be invaluable, and more than a compensation for diminished money-profit, when the result of the change; and that no individual planter in our colonies, were it optional to re-establish slavery, would hesitate a moment in declining it, as a great evil got rid of, as a great sin in itself, and a great temptation to sin avoided.

Science applied to colonial agriculture has already advanced it, and unquestionably may and will advance it very much further.

The same science applied to the process of manufacturing sugar is having a like effect, and, if encouraged, will make progress and accomplish wonders. I use the word advisedly; the result of science being so often such, till the feeling implied in the word ceases with the novelty. Were not additional duties levied on sugars of improved quality made in our colonies, were the *ad valorem* duty abolished on our colonial sugars, and such a a duty laid on foreign sugars, *that* would be an encouragement in point, as much so as the imposing a higher rate of duty on such sugar as now practised, has a contrary, a disheartening ten-

dency, arresting improvements, checking the application of science, and mortifying the individuals who have made the exertion. The loss of sugar and molasses on the homeward voyage, from fermentation and leakage, is enormous, greatly either to the enhancement of the market price to the consumer, or a diminution of profit to the producers. Were only sugars of the best quality imported or those prepared according to the methods pointed out by science, no such losses would be sustained; and foreign countries might adopt the same system of duties in relation to sugars, which, if fairly carried out, it is believed would materially conduce to prevent the undue extension of cane cultivation; might promote a sounder, safer state in the great sugar growing colonies; prevent the terrible catastrophe of servile war, such as desolated St. Domingo; and rapidly lead to slave emancipation, considered even as an economical measure.

In connexion with the same interest, let us briefly advert to the people—the population of our West Indian colonies.

The African is peculiarly fitted to the climate of the West Indies: there, and in situations most unfavourable to the European, he enjoys health not inferior to that which he experiences in his native country. As a labourer, he has not, perhaps, his equal for power of endurance and resist-

ance; and, were he what he might be made, he would be invaluable; that is, if to his bodily good qualities were added certain mental ones, such as skill, improved intelligence, and honesty — qualities that might be imparted by education. It is pleasing to find that in youth the negro has a great aptitude to learn, and a desire to be instructed; and also, that whatever his capacity may be for the higher branches of knowledge, in which hitherto he has scarcely been tried, it is admitted by those best acquainted with him, that he is fully equal to the making of such attainments as are connected with advanced civilisation. The persuasion that his education — one judiciciously directed — is required equally for his own good, as a moral agent, and for the good of society and the successful competition of free with slave labour, is now matter of conviction, and is beginning to have effect in increased exertions to open schools, and to introduce in them an improved method of teaching; which, it is to be hoped, as is expected, will be conjoined with the forming of industrial habits.

What is applicable to the labouring class in England, as expressed in verse by the great moral poet of our times, is even more forcibly so, if possible, to the same description of persons in the West Indies, especially now, since the abolition of slavery: —

"—— The discipline of slavery is unknown
Amongst us; hence the more do we require
The discipline of virtue; order else
Cannot subsist, nor confidence, nor peace.
Thus, duties rising out of good possest,
And prudent caution needful to avert
Impending evil, equally require
That the whole people should be taught and train'd.
So shall licentiousness and black resolve
Be rooted out; and virtuous habits take
Their place; and genuine piety descend
Like an inheritance from age to age." *

The West Indian—the planter, the proprietor, to allude to another and higher class—has commonly been charged with many faults, such as want of energy, idleness, deficient intelligence, deficient enterprise. Circumstances considered, perhaps it was natural to expect that such would mark his character. Speaking from my own experience of him, I have no hesitation in expressing the opinion that he is not deserving to be so considered, and that he has far more of the opposite qualities than could reasonably have been expected from his situation. His industry and intelligence are denoted in the high state of culture of the land; his activity and strength in the bodily exercise which he daily takes in the superintendence of the operations of agriculture, and the fatigue

* From "The Excursion," B. ix. By Wm. Wordsworth.

which he is capable of enduring. In brief, whilst in mental attainments he is not inferior to the English country gentleman, perhaps he exceeds on an average in this respect — he is his equal almost in bodily vigour; presenting, in this latter relation, a remarkable contrast when compared with the East Indian. No palanquin is used in the West, no luxurious hookah, no pomp of attendance of servants, not even now a running footman, or horsekeeper, or groom.

These remarks are applicable only to the higher order of the white population of the West Indies, no wise to the inferior, to the working class, who are too commonly steeped in vice connected with intemperance, and are altogether a degraded and diseased set, and that both in body and mind. A large number of them are paupers and beggars: in brief, it is only in this class that abject poverty is found, and objects of commiseration; it is rare indeed to be asked charity by a negro or coloured person — during three years I only recollect two instances of the kind.

These colonies, as cultivation is carried on at present, and in their present settled state, are altogether unsuitable to the European immigrant of the class of day labourers. Every circumstance is unfavourable to him — unfavourable to his health, unfavourable to his morals; and, without exception, unless in the instance of the Portuguese,—

and they are hardly an exception,—every attempt that has of late years been made to introduce such labourers has proved more or less a disastrous failure.

For the West Indies to prosper, and for free labour to compete successfully with slave labour to its overthrow, what seems most requisite is, the giving a scientific education to the higher class—the proprietory class, the directing mind,—and a religious, moral, industrial education to the inferior class, the labouring body. Were this accomplished, were there science to direct skilled and honest labour, the triumph of free labour could hardly fail of completion; that is, in such an island as Barbados, where the number of labourers is quite equal to the extent of land under culture, or to any other colony similarly situated.

Other conditions might be mentioned as likely to promote this triumph, such as ceasing to associate with colour any ideas of inferiority or superiority,—putting the coloured man, *cæteris paribus*, on an equality in society with the white man,—giving encouragement to the coloured man to raise himself in the social scale by merit, and, what we are sure is important, and nowise problematical, discouraging, at the same time, withdrawal of labour from the mart of labour, and the field of agricultural improvement—the large estates, and those of moderate extent, to small patches of pro-

vision grounds, just capable of supporting a family in the mere necessaries of life, living very much after the manner of brute animals.

In offering the preceding remarks, I have always had Barbados in view. To the other West Indian colonies they are generally more or less applicable, it is believed, as they resemble Barbados or differ from it. Those most resembling it are Antigua, St. Kitts, St. Vincent; enjoying similar free institutions, and settled chiefly by planters from the United Kingdom: those least so are the conquered or ceded colonies, such as British Guiana, Trinidad, St. Lucia; which were settled first by foreigners; which have not the same free institutions; which seem more helpless or discontented; and also, probably in consequence, less inclined to exert themselves for the public good; considering labour in such a cause a mark of weakness, that is, if gratuitously given.

In thus noticing British Guiana and Trinidad, it would be wrong to pass over redeeming circumstances. A debt of gratitude is due to the local government of the former for its enlightened liberality in establishing and supporting a colonial laboratory for the purpose of research, with the ultimate object of improving tropical agriculture and the manufacturing processes, happily placed under the superintendence of a zealous and able inquirer, Dr. Shier. A like debt is due to the

nobleman, the Governor of Trinidad, for the exertions he has made to advance the agriculture in connexion with the general welfare of that fine island. A good judge on the spot, Dr. Mitchell,—an individual who has laboured hard in the cause, with a zeal and activity rare within the tropics, and a large extent of knowledge,—in one of his latest publications, "Suggestions on the Making of Sugar," observes, should his remarks have the desired effect in rousing the planters to exert themselves, "the credit of such a result will be due to the noble and disinterested zeal of Lord Harris."

LECTURES.

LECTURES

ON

THE STUDY OF CHEMISTRY.

LECTURE I.

INTRODUCTORY.

ON SOME OF THE USES OF CHEMISTRY.

WITH the desire to aid in a good cause, viz., that of promoting the advancement of the "Reid School of Practical Chemistry," and to endeavour to excite a taste in connection with that school for chemical study and inquiry, I willingly come forward to address you on this occasion, considering it a duty so to do, and at the same time a privilege and a distinction.

With the objects in view as just stated, it is my intention to bring under your notice some of the uses of Chemistry, on which necessarily the interest belonging to the science, and its importance, depend.

If you reflect on what Chemistry is, viz., that science which treats of the composition of bodies, and their action on each other as affecting composition, and the properties of bodies as thus exemplified,—reflecting, I say, on this, you can have no difficulty in understanding how wide is the dominion of chemical science, and how important it is in its various relations, whether we look to the useful arts, to the common processes on which even more than the comforts of civilised life depend, or to the economy of Nature, in its vast extent and almost infinite variety — such as we witness it in all its amplitude on this our globe.

To have a just idea, however, of this wide range of chemical science, and of these its important bearings, something more than a mere reflecting on an abstract or general definition is requisite: it is necessary to consider particulars; and, as an aid, I shall adduce some instances.

Let us begin with some of the common processes essential to the comforts of civilised man, indeed more than essential, as, without them, his mode of life, as well as we can imagine it, would be little different from that of the brute animal. No tribe or race of people, however rude, has yet been discovered destitute of the knowledge of the manner of kindling fire, and of using it for good and for evil purposes. This knowledge, the ac-

quisition of which is hid in mystery, and has been the subject-matter of fable — this, which may be held to be one of the distinctive marks between man and the brute — is, in practice, a purely chemical process, and one requiring, to conduct it in its very numerous applications with the most perfect success, not an ordinary, but a profound, acquaintance with Chemistry.

Fire having been for a long time the great agent of the chemists, they of the old school, the alchemists, as in their pride they were pleased to designate themselves, were named Philosophers by Fire. This I notice to show its early connection with Chemistry. It is still an important agent in the chemical laboratory, as it always must be; and it remains, as you are aware, the great agent of some of the most considerable of the chemical arts.

It would be premature in this place to do more than to notice briefly the process of combustion in relation to its nature. It may be defined to be the result of intense chemical action, or the rapid union of certain bodies capable of combining chemically. Two or three instances may be useful: —

The burning of a candle, a compound body, is a familiar example. If introduced into a limited portion of atmospheric air — which is a mixture of 21 parts of oxygen in volume, and 79 of azote

— it will burn for a short time, and then go out. Were we to examine the air afterwards, we should find nearly half of the oxygen deficient, expended in forming water by uniting with the hydrogen of the candle, and carbonic acid by uniting with its carbon ; and it may be inferred that the flame expired before more oxygen was consumed, in consequence of the action of union ceasing to be sufficiently intense or rapid to evolve the degree of heat essential to inflammation ; and that this, moreover, was owing to the dilution from the azote present, and the carbonic acid and vapour of the water formed.

Phosphorus, sulphur, carbon, and the various metals, are not compounds like the substances used for giving light, such as wax, oil, or tallow, or as wood or coal, the ordinary materials of our fires, but are simple substances, that is, bodies not yet decompounded. Some of them unite rapidly with oxygen, or with one another, so rapidly, and with such an evolution of heat, as to produce fire. The union of phosphorus and oxygen, and of copper and sulphur, are striking examples of the kind, and are easily shown. In the one instance you will witness a most brilliant inflammation ; phosphorus, being volatile, combining with a substance in a gaseous state, the oxygen. In the other you will witness the production of a red heat, or simple ignition ; the

copper not being volatile, though combining with a substance that is so, the sulphur.

In some chemical writings you will read of combustibles and the supporters of combustion, and find bodies thus divided into classes. The arrangement is an artificial one, affording no help whatever to the explanation or understanding of the phenomena; on the contrary, tending to give erroneous ideas of the nature of combustion. Thus hydrogen and oxygen were once considered as distinguished instances of the two kinds; yet if a stream of oxygen be passed into an atmosphere of hydrogen, and an electrical spark be applied to it, the phenomena of inflammation will be the same as if the stream were of hydrogen passing into an atmosphere of oxygen, the oxygen seeming to burn in the one instance as the hydrogen does in the other; the fact being, as before noticed, that the combustion is the result of the union of the two.

From fire let us now turn to water, which has been considered its opposite, and which is not less necessary to man as regards his *ordinary* wants; putting aside that, like air, it is essential to the maintaining of life. Water, you know, was long believed to be an element: the discovery of its composition, that it consists of oxygen and hydrogen, was coeval with that of the beginning of the science of Chemistry; and *that* is so recent, that I

have been in the company of the two distinguished men — Cavendish and Watt — who divide the honour between them.

As the skilful management of fire requires an accurate and extensive knowledge of its nature and qualities, so, too, does the use of water. Pure water, by itself, is liable to no change: it neither putrefies nor decomposes. But it is a great solvent,—a great agent of change,—and, in consequence, no water that is not artificially prepared is pure; and, owing to what it holds in solution, it acquires new properties, which may be either beneficial or otherwise, according to the qualities of the substances dissolved: poisonous if there be lead or arsenic; not injurious if lime or common salt in exceedingly small quantities; and medicinal, that is, beneficial in certain states of disease, if holding in solution particular substances, such as iron, sulphur, iodine, &c. A knowledge of what it holds in solution should direct its use; and if what it holds in solution unfit it for certain purposes, the same knowledge will direct how the separation of the noxious ingredients may either be effected, or their introduction prevented. For instance, the hardness of water, to use a common expression, rendering it little fit for washing, depending on the presence of salts of lime, is corrected by the addition of a little alkali, which decomposes these salts. Lead, in a very minute

quantity, in the form of carbonate of lead, is sometimes dissolved in water by means of carbonic acid gas, rendering the water highly noxious, imparting a poisonous quality, which slowly and obscurely takes effect; and, what is remarkable, the softer, the purer, the water, the more likely it is to become thus impregnated if kept in a cistern lined with lead, or conducted through pipes of this metal. When detected in water, — and the detection is easy by sulphuretted hydrogen, which throws down the metal in the form of a black sulphuret, — the prevention of the like evil for the future is also easy; which is, by having the cistern or pipe slightly incrusted by an insoluble compound of lead, by keeping these full for a short time of water of a hard quality, containing, for instance, a small portion of sulphate of lime, or of sulphuric acid alone; this acid uniting with oxide of lead, and forming the compound required.

These few instances are almost sufficient to show you how intimately Chemistry is concerned in administering to our ordinary wants. Innumerable examples might be given in confirmation. This may be said with truth,—that the more comforts we have, the more conveniences and helps, the more we are indebted to Chemistry. It is difficult to mention any part of household economy

that is not under obligations to it. By means of simple processes, directed by chemical science, mainly consisting in the entire exclusion of atmospheric air, perishable meats and fruits are preserved, and a commerce in them established to the most distant regions of the globe. Directed by the same science, air which burns with a brilliant flame is obtained from coal and oil, and is now in general use in most of the cities of Europe, for the purpose, as you know, of lighting streets and houses. Here is an example of it. This bladder is filled with coal gas, and may be kindled, as I shall show you. The same gas is evolved in the burning of a candle or lamp; and the light obtained is in consequence of its combustion. Little more than fifty years ago, coal gas was first tried, for the purposes of illumination, by Mr. Murdoch, to the surprise, and almost consternation, of those who witnessed it; and it was in a mining town of Cornwall. That experiment, then so thoughtlessly received, has since been developed in great works, in which millions of capital are invested, productive of an economical and powerful light, and in the preparing of which various products are obtained, all of value, and applicable to many uses; such as coke, the residue of the coal; such as tar, naphtha, and certain salts.

Other improvements in the manner of lighting our rooms we owe likewise to Chemistry; such as

lamps which burn without smoke, owing to the manner in which air is supplied to the flame; such as candles almost of the firmness of wax, and possessed nearly of the same good qualities, but greatly cheaper, made from one of the ingredients of common tallow candles, that which is solid, by the separation of the other ingredient, which at ordinary temperatures is a liquid oil.

Economical and improved methods of warming houses, where that want is required, are other instances, similar to the preceding, of what Chemistry has effected in relation to our immediate wants. Cooling processes, the making of ices, the luxuries of hot climates, are under the domain of Chemistry, and were little known till chemical science was advanced. And it is curious to remark, that *one series* of original experiments, those on latent heat, made by a chemical philosopher, Dr. Black, may be considered equally the basis of the artificial cooling processes to which we owe the luxuries alluded to, and of those refined researches and inventions of Watt which terminated in the perfecting of the steam engine—an instrument before his time feeble and of little use,—which he made what it now is — the great mechanical power of the age.

I shall dwell but briefly on the useful arts in their connection with chemical science, for the purpose of illustrating the extent and importance

of this science, the connection now being so generally understood.

Of the arts referred to, how many there are which are purely chemical; such as the reduction of the metals from their ores, and the various other processes of metallurgy; the making of glass, of porcelain, even of brick and tiles; the burning of lime; the preparation of mortars;—arts affording materials for so many other arts: and the same remark applies to tanning, dyeing, and bleaching. These are only a small number of the chemical arts; it would be tedious to give a complete list of them, including those which, if not strictly chemical, are in part so. Mining is an example of this, as in the instance of the coal mine. The extraction of the coal from the earth, from the seam or bed in which it is found to occur, is the rudest of operations when conducted in a primitive manner, as I have witnessed in the Turkish dominions in Asia Minor, where a coal bed is worked very much in the same manner as a marl pit is in Barbados. But how different is the operation at home; and, though infinitely more difficult, greatly more profitable. The power of steam, by the steam engine, is variously applied; gunpowder is largely used; light, when there is danger of destructive explosion from inflammable air, is obtained by the use of a lamp that has the property of confining flame,—of filtering, as it were, heat

from light, allowing the greater portion of the light to pass, and retaining the larger portion of the heat; thus affording safety; a high temperature being requisite to inflame coal gas — the destructive agent in coal mines.

We have other examples in mining of the introduction with excellent effect of chemical processes. The natives of America, when first discovered, were remarkably ignorant of chemistry, considered as an art, even in its rudest state, such as it was in the Old World in the earliest historical periods. They were totally unacquainted with iron. The only metals they used were gold and silver, which they met with in their native state, and which of all metals are in that state most easy to work. It is from this quarter of the globe that a large portion of the precious metals has been obtained; and their quantity, consequently, in use in modern times has been so greatly increased. But other methods than those of the unskilled aborigines have been employed in obtaining them, otherwise the supply would soon have been exhausted. Gold and silver have the property of combining with mercury, forming what is called an amalgam. It is by employing mercury by means of the process of amalgamation that such enormous quantities have been obtained, the mercury detaching these metals from whatever they are mixed with, and

uniting with them, however minute the particles; and even the more readily in proportion to their minuteness, as when occurring in the form of invisible granules.

And here I may point out that the power of chemical science, in relation to the useful arts, can hardly better be illustrated than in the results of chemical research employed on the native gold dust of America; that which is collected by washing the auriferous sands of the beds of rivers and other alluvial districts of that continent. Scientific chemists engaged in this research have discovered no less than six new metals; one of which, and the first that was made known, is platinum, a metal that exceeds all others in weight, is infusible in the fires of our strongest furnaces, is capable of welding like iron, is not liable to rust or to be acted on by the most powerful of the acids, and, in consequence of these peculiar qualities, is highly valuable for all purposes for which these rare properties render it fit—whether it be the touch-hole of a fowling-piece, a crucible or other form of vessel for use in the laboratory, or a retort to be employed in the manufacture of certain powerful acids. And here I may mention that the cost of a single retort of this metal, for making oil of vitriol or sulphuric acid, which sells for a penny a pound, has amounted to one thousand pounds sterling. This

may give you some idea of the capital invested and the science associated with it, and the economy the result, — and, it may be taken for granted, not without profit to the manufacturer. The example, I apprehend, admits of application here; and should encourage those gentlemen who now, in consequence of wide competition, are striving by skilled and improved processes, both in the cultivation of the cane and the manufacture of sugar, to earn success — that is, profit with low prices.

It is a truism now, that knowledge is power. Its best illustrations are afforded in the useful arts. I have mentioned, perhaps, sufficient to convince you of this. At the present time, wherever we turn our attention, to whatever chemical science has been applied, we see it strongly exemplified. I shall bring forward only one instance more, for fear of wearying you; and it shall be likewise from metallurgy. Most of the lead of commerce is extracted from galena, which is a native sulphuret of lead — that is, a compound of this metal and sulphur — and which commonly contains a small proportion of silver. When the art of reducing the ore was rude, this silver was in a manner lost; it remained incorporated with the lead, to which it imparted no increased value; indeed, its presence was for a long time unknown. Now it is carefully sepa-

rated, by a process remarkable for its simplicity. Contrary to what might have been expected *à priori*, lead being a very fusible metal, and silver very much less so, an alloy of the two is even more fusible than lead itself. This property is taken advantage of for the purpose of detaching the silver. The fused metal after reduction, that is, the lead containing a small proportion of silver, is cooled nearly to the point of consolidation, and is then poured on what may be called a metallic strainer, a large iron ladle or basin with small holes in it: the more liquid alloy passes through; the lead, becoming solid, is retained in it; and, ultimately, the silver is procured pure, detached entirely from the lead with which thus alloyed, by the process of cupellation, consisting in exposing it to a strong blast of air on a support of bone earth, when the lead, being converted into litharge, is absorbed by the cupel of bone earth, leaving the silver isolated on its surface, the bone earth not being absorbent of the fused metal. The quantity of silver thus extracted in England alone from the ores of lead is very considerable; and the individual who first suggested the process, founded on the property mentioned, derives from it by a per centage an income of several thousand pounds a year.

I have spoken of the connection of Chemistry with the economy of Nature. Were it only on

this account, apart from our ordinary wants — apart from the useful arts — the science would be deserving of careful study, and would amply repay it. Every region — the atmosphere, the ocean, the solid earth — and that both at its surface and in its depths, may be considered as a laboratory, in which chemical changes are constantly in progress, and effects and phenomena are produced without intermission, of a wonderful kind, in admirable harmony, and demonstrative of an Intelligence, may I say, in the ordering of them, truly Divine. Were the air constituting the atmosphere in any way different from what it is, we could not inhale it without perishing. Formed of a *mixture*—of a *mixture*, not a *chemical union* — of oxygen, azote, carbonic acid, and aqueous vapour, each of these ingredients has a useful part to perform, and that almost equally, as regards the two great orders of beings possessed of life to which they administer, viz., vegetables and animals. The atmosphere and the soil nourish and support vegetables; the former, and vegetables, sustain the life and growth of animals; animals, in living, contribute, by what they throw off as noxious or superfluous, to the support of vegetables; and, finally, in dying and in undergoing decomposition, they restore their borrowed material elements to the atmo-

sphere and the earth for renovation in new forms of life.

These are great facts, which have been ascertained by chemical research. It is this research which has analysed the atmosphere, and determined its elements, and their proportions and properties; which has analysed the ingredients of the solid earth, and determined their kinds and qualities; and has done the same for the water of lakes, seas, and of the ocean; and also ascertained the relations existing between all three, comprising, with the living beings which inhabit them and the imponderable substances by which they are acted on, the wide and vast economy of Nature,—happily so called from the just and beautiful arrangement, order, and adaptation of its several parts.

Moreover, these studies cannot fail to be useful intellectually, tending as they do to form the reasoning powers in youth, and strengthen them in manhood; tending moreover, as I would hope they do, to exercise a salutary influence on the mind, to make it more humble, hopeful, and truthful. Humble, by the comparison we cannot fail to make, on close and minute examination, between the perfection of the works of Nature and the imperfect works of man; by the comparison of the small extent of what we call knowledge, with the vast amount that we are sure we are ignorant of;

hopeful, that is, of farther progress and improvement, considering the advances that have been made, in a few years, by right methods of research, viz. carefully conducted experiments; and truthful, from having in these inquiries to do with precise results, determined by weight and measure, and subjected to various tests to avoid fallacy; a mistake in a chemical inquiry, an error unintentionally committed, vitiating, *it may be,* a whole course of laborious trials, making them useless, or worse than useless, and leading, if persisted in, not only to wasted labour and vexation of mind, but also, as *it has been,* to loss of reputation. The conviction of the value of exactness impressed thus on the mind, tends to give it a habit of exactness and correctness, and that both in conception and expression; and the habit once formed necessarily influences the character of the individual. The truths, too, unfolded by chemistry, have, I believe, a kindly and expansive influence, not unlike that of Christianity in its true spirit. Chemistry teaches that there is nothing vile in God's works; that everything material, however mean and common it may be, vulgarly considered, has useful properties, and is in no wise deserving of slight. Take an example, and it shall not be a low one:—chemical, united with physiological science, teaches us that our coloured fellow creatures have so different a hue from that of the inhabitants of

cooler regions, not as a distinctive mark of inferiority, but to fit them for the warm regions they inhabit, the dark colour of their skin being a protection from the scorching, blistering effects of the sun's rays; it being the property of black surfaces, whilst they do not reflect radiant heat, to convert such heat into that not radiant, and which in its effects is comparatively feeble.

My friend, who preceded me, very justly pointed out a difference in the influence of classical literature, in mental training, and that of science. There is a marked difference, too, I cannot but think, in the influence of science, especially of chemical science, and of that of the fine arts on the mind. The cultivation of the fine arts is little connected with that of the reasoning faculty; it is more connected with sense and taste than intellect; I say more, because no great advance in these arts can be made, or duly appreciated, without tasking the intellect; taste even, refined taste, having its foundation in judgment and a certain propriety belonging to the moral feelings.

Chemistry, by enriching the mind with facts, giving it some insight into the wonders of nature and of art, may tend even to improve the taste, especially when in danger of being depraved by false sentimentalities. Much of that feeling which is commonly called poetical depends on associations. The ship with the flowing sail, the lowly cottage

embowered in wood, the curling stream of blue smoke, rising gracefully and marking the spot, are considered commonly and spoken of as poetical objects; whilst the railway, the steam-vessel, the steam-engine, are not commonly so considered; and is it not because they are generally viewed, and thoughtlessly, in the light of objects associated with traffic, the property of a company, and administering to common wants, without regard being had to the high invention, the exquisite skill, the immense labour, exercised in their construction?—seen in connection with which surely they are better fitted to excite admiration than even a sailing vessel, so much at the mercy of the winds, or a lonely cottage, too often the abode of vice and misery, or its blue smoke, which is most remarkable for this tint when the incumbent air is damp and likely to be unwholesome, or when the fuel used, wood or peat, abounds in moisture.

These studies have a further recommendation as a part of education. The power of observing is a very important one; and, because universally exercised in a certain manner, unavoidably so, throughout life, it is little thought of, and rarely cultivated with a view to improve it. How wide is the difference between two individuals, the one formed to habits of accurate and minute observation, the other an observer in the ordinary way; the one sees thousands of objects that the other

never notices; the one never has to complain of want of objects to interest him, surrounded as he almost everywhere is by the inexhaustible riches of Nature and her wonders,—hieroglyphics, as it were, which he has acquired the power of reading. The growing blade of grass, the green leaf of a plant, or the same in its withered state, the dew-drop, in its composition, form, and effects, the excrementitious matter of an insect,—there is nothing, in brief, I can mention which meets his eye in the external world, that does not, or may not, at different times, incite to reflection and that to inquiry; and as the thinking faculty has the impression from the sense, so that faculty in return sharpens the sense and gives it power. Chemistry, then, practical chemistry, is particularly fitted to aid in advancing the use of the senses in the way alluded to. Each sense in chemical inquiries is more or less exercised; not only that of sight, but also that of smell, taste, touch, and, though least of all, even that of hearing. The colours of the metals exhibit fine distinctive shades of difference; certain bodies have characteristic odours; others impart to the touch a peculiar and distinctive feel; and some emit sounds, when bent or struck, which disclose their nature. In chemistry, then, as a study, the senses are cultivated to minute and accurate discrimination in connection with, and subservient to, the judgment and reason,

which, I cannot but think, is no mean advantage as regards mental culture.

Moreover, chemical pursuits are not only well adapted to sharpen the senses and improve the powers of observation, but they are also useful in affording exercise to the body. Chemical inquiry is not a sedentary occupation. The practical chemist must be alert and active: he can seldom sit down when he is making an experiment; his hands are almost in constant use; there is hardly a muscle of the frame that is not brought into action from the varied positions of the body required when engaged in experimental research; and, as he has often powerful agents to deal with, destructive in their effects if not well managed, there is a motive at the same time both to alacrity and exactness, with vigilance, in the movements necessary, hardly less than on the part of light infantry when skirmishing in advance with an enemy, — a little danger in the one instance, as a great deal in the other, adding much to the interest of the operation, — or of the exploring navigator, conducting his vessel through unknown seas, constantly on the alert, and necessarily so, to avoid the dangers of rocks and shoals.

There is another, and not inconsiderable advantage belonging to chemical pursuits, which I must not pass over in silence. I allude to the amusement and recreation which they afford when

engaged in experimentally, the only way in which they can be entered on advantageously. In a rainy day in the country, the amateur of chemistry need not feel tedium from want of active occupation: the student may rise from his book or desk, when wearied with reading or writing, and find relaxation and amusement in his laboratory, however humble and limited its apparatus; the merchant, the man of business, the tradesman, when weary with monotonous and dull details (if they are so, as they appear to be), may refresh and invigorate his mind by turning to these pursuits; and in many instances he may make them subservient to his interest. There are many examples I could refer to, in illustration of what I have just advanced: I shall notice only one, for I know no one more remarkable — that of Dr. Priestley. The studies he was engaged in, which he considered most important, on which he laboured, I may say, sweated his faculties most, were those chiefly of a theological kind; chemistry he made his amusement; he thought, in consequence, little of his chemical labours, in comparison, and yet his reputation, a very high, and it must be an enduring one, because he was a discoverer, mainly rests on their results. I have said that he was a discoverer, and so his reputation must be lasting. No chemist discovered more new substances; scarcely any one has done more

to advance the science of chemistry. And yet his means were small; his knowledge, when he began to experiment, most scanty; whilst he was learning, he was discovering; affording altogether a memorable example of what may be accomplished, even when making scientific research a recreation.

I have laid stress on engaging in chemical studies experimentally; allow me to say a few words more on this point, especially, considering that it is a school of practical chemistry that we are endeavouring to establish, — the Reid School of Chemistry, — and to engraft, as it were, on Harrison's school of preliminary instruction; the place where we are, the audience assembled suggesting and warranting, I would hope, the remark, and affording promise of success, both as to a permanent connection of the one school with the other, and the right direction of the studies in both.

Unless experimentally conducted, chemical studies will make little impression on the mind, will fatigue rather than interest it, and will turn to little good account. Experimentally followed, they cannot, on the contrary, fail to amuse, interest, and instruct, and to make impressions hardly to be forgotten, the senses as well as the judgment being at the same time appealed to. The difference between the study of chemistry in books and in the laboratory is even greater than

that which exists between reading the account of a country and travelling through it oneself; inasmuch as from the similarity there is between one country and another, and our acquaintance with the majority of objects such as are common to both, we are, in a manner, prepared to understand the description of that which we have not seen from the knowledge we have of those with which we are familiar. But, as regards chemistry, the situation of an individual not practically instructed is very different: a large number of the objects of chemistry not being common objects; very many of them being of recent discovery; many of them of a subtle nature, almost eluding the senses, and entirely eluding them unless made confessed by the help of experiments.

In carrying on the study experimentally, moreover, I should not omit to mention an advantage which I have not yet noticed, which is, the exercise of the inventive faculty. This faculty is necessarily brought into operation in varying the trials, so often requisite to arrive at a satisfactory result, and in contriving apparatus for the purpose. No pursuit that I know anything of is equal to chemistry in this respect; and in no one, I believe, has the faculty in question been more remarkably developed, as shown in the discoveries that have been made.

Whilst I wish thus to impress on your minds

that chemistry, an experimental science, is most advantageously cultivated by means of experiments, and that it can only thus be studied successfully and with pleasure, do not suppose that I would imply that reading is not necessary. The reading, and the consulting of chemical works, is essentially necessary to the chemical student; books are not less required by him than apparatus: the one for instruction and direction, the other for practice and demonstration. And yet, such is the value of experiments, that often, on a doubtful point, when the exact recorded fact has escaped recollection, it will be more easy to the advanced student or chemical inquirer to determine it by trial, by experiment, than by reference to an author, especially in these times, when a good index to a book is so rarely to be found.

I may add, that as no satisfactory advance can be made in chemical inquiries without taking notes of the results of the experiments in progress, this necessarily conduces to facility and likewise to accuracy in writing, in itself no small advantage.

There is another point on which I wish, with your permission, to offer a few words. It has been said, and often repeated, that a little knowledge is dangerous, and is to be avoided. You, I hope, are not of that opinion. I believe it would be more correct to maintain, that it is not a *little knowledge*, but the *want of it*, that is dangerous;

or, that crude, imperfect, unsound knowledge, if the term be admissible, is dangerous, and to be avoided. I allude to this, satisfied that chemistry affords a refutation of that which I hold to be a fallacy; and as such, giving no small degree of encouragement to the commencement of the study, provided it be entered upon experimentally. I have adduced the instance of Dr. Priestley, as an example of the learner and discoverer combined; he, too, is a striking example in point as regards the present question. He began the study of chemistry very much after the manner that a child begins the study of the external world — almost in total ignorance. He described results as he obtained them — the results of his trials — faithfully and minutely. They were new to him necessarily; they were new to the world many of them; and these consequently were discoveries. Thus proceeding, continually experimenting — it was an auspicious time that in which he lived, in the infancy of the science, when so much was to be discovered,—thus proceeding, he gained knowledge more and more, and became distinguished as a chemical philosopher.

Apart from the consideration that all knowledge must have a beginning, be very limited for a time, and comparatively limited however advanced, — that being the attribute of human knowledge, — apart from these considerations, I may say,

that however small the degree of chemical knowledge may be, provided it be exact, it may be turned to account. It may not be amiss to adduce a few instances.

Here, before you, are two specimens of sand, one from the shore of Carlisle Bay, in this island, another from the sand hills in the parish of St. Andrew, near the sea: viewed cursorily, they seem little different in appearance; and yet they have marked differences of qualities depending on their composition, and which are most easily ascertained by chemical examination, and, in consequence, they are fit objects to engage the attention of the young chemist. If he pour an acid on the sand from St. Andrew's, he will find that it will have no more effect than if he had poured water on it. Making the same trial on the sand from the shore of Carlisle Bay, he will find that a violent action will take place, an effervescence from the disengagement of gas produced, and that in a short time the whole of the sand will have disappeared, having been dissolved almost entirely by the acid. These results will enable him to decide that the first kind of sand is siliceous—and if he forcibly rub glass with it, he will find that it will scratch the glass, insolubility in most of the acids, and hardness sufficient to scratch glass, being characteristic qualities of silica; and will enable him also to decide that the second kind of sand consists chiefly

of carbonate of lime, which he will naturally infer is derived from sea-shells and coral; and this inference will be confirmed by minute ocular examination of the sand, when he will have no difficulty in satisfying himself that if not each particle, at least each of the larger ones, is a fragment either of a shell or coral; and the very little matter remaining undissolved by the acid — delicate flakes of animal matter — will strengthen the conclusion.

Let us take two or three other instances. The chalk-like specimens before you are very similar, you perceive, in appearance; they are from the higher parts of Barbados, on the verge of or within the Scotland district. Though so similar in appearance, they are not so in reality; and, like the sands, they are fit subjects for the young chemist to experiment on. This one we shall see will effervesce strongly with an acid, being composed chiefly of carbonate of lime; this other not at all, consisting as it does chiefly of siliceous matter; and not of common siliceous matter, but of the skeletons, millions in number, — rather, I should say, in numbers incalculable, — of microscopic animals of many different species; and the third also not effervescing, and yet different from the last, as it contains no visible organic remains, but silica in a very finely divided state, mixed with alumine and

magnesia, constituting a compound somewhat between marl and clay.

These experiments, though so very simple and easy to be made, are not uninstructive. How useful the information they afford may be to the agriculturist, pointing out to him, as they do, that one kind of sand or of chalk added to a soil deficient in lime, will supply that deficiency; and that others, like it in appearance, will not answer the purpose. It admits, too, of various other applications, which I must not occupy your time in dwelling on, both in the arts and in connection with geology, or that science, the object of which is to make us acquainted with the structure of the globe we inhabit and the changes it has undergone.

May I add another example? There is a mineral, iron pyrites, possessing the lustre, and a good deal of the colour of gold, which has been the cause of much expensive delusion, having frequently been mistaken for the precious metal, and thus led to costly and fruitless mining operations. More than once since I have been in Barbados, small portions of it have been brought to me, with the somewhat anxious inquiry, whether they do not contain gold; and very lately I received from a friend, as a specimen of gold found in South Carolina, and sent to him from thence as a valuable mineral, a sample of the same kind; proved to be so by subjecting it to a

chemical trial of the simplest kind, such as the student could make with the greatest facility and confidence in the result, viz. the immersing it in nitric acid slightly diluted; under the action of which the glittering gold-like matter disappeared with effervescence, being dissolved,—a proof that it was not gold, which is insoluble in this acid;—and some ferrocyanuret of potassium having been added, threw down a dark blue precipitate, demonstrating that the matter dissolved was iron.

The same mineral, iron pyrites, is not unfrequently associated with another, closely resembling it, viz. copper pyrites, a compound of copper, iron, and sulphur. By the experienced miner it is easily distinguished by its richer yellow hue, its purple tints or stains often intermixed, and less hardness; by the inexperienced it is sometimes mistaken for iron pyrites. Very lately I received a specimen from Trinidad so designated. It was in reality a mixture of iron and of copper pyrites, the former predominating; and, in its indications in relation to mining purposes, not unimportant, such a mixture, especially as in the instance of this sample, quartz forming a part of it, auguring well for the discovery of a vein of copper ore, which might be worked with profit. Now the chemical student, though but little advanced, might, by an easy experiment, enlighten the inexperienced miner. Reducing

the ore to powder, and acting on it by dilute nitric acid in excess, he would obtain a solution, the colour of which would denote the presence of copper, which would be confirmed by the addition of ammonia in excess, when two different effects would be produced, a brown precipitate and a blue solution, the one of the peroxide of iron, the other of the peroxide of copper.

Commencing with such simple experiments, and obtaining such results, will there not be encouragement to the student to continue and extend them? The mind of man is ever active; the love of knowledge is universal: the one too often ill directed in its energies; the other too often all but dormant, or unexcited. Chemistry, I hope I have shown, affords ample scope for both; and I can confidently promise, that, if experimentally followed, it will unceasingly yield worthy objects for the mind to be exercised on, useful and elevating; and which, in a commensurate manner, will cherish and gratify that other fine quality of human nature, the love of knowledge and of truth.

I hope, in the statement I have now made to you in favour of the study of practical chemistry, I have not appeared to exaggerate its usefulness and value. I say, *I hope*, because there is always a tendency to appreciate highly, and comparatively, perhaps, too highly, any pursuit to which

one's attention is closely and continuously given; and especially if it be of a kind to excite an enthusiastic interest — an attachment.

If any qualifying condition be requisite in this my eulogy of chemistry, I would wish to impress on your minds, especially of the younger part of my audience, that, like every other branch of natural knowledge, it should be kept in subordination to moral science. When the moral and religious foundation is laid in youth, then natural knowledge, it is presumed, may be sought after with safety, — in the certainty that every truth developed in the external world will tend to fortify the mind through the moral sense; and this by proving that, when largely and comprehensively considered, there is a harmony between the merely physical and the moral, and a consistency and accordance in whatever is true, whether belonging to the world of sense, or to that which is higher and is intellectual.

LECTURE II.

ON THE ATMOSPHERE.

Having, in the preceding lecture, pointed out some of the varied uses of chemistry, it is my intention, in further illustration of the subject, to bring under your notice three great departments of nature, the three distinct regions into which the globe we inhabit is divided, viz. the atmosphere, the earth, and the ocean; in treating of which, an opportunity will be afforded, on a scale even too vast for the occasion, for impressing on your minds how intimately the science of chemistry is connected with the economy of nature, and how imperfectly and inadequately this admirable economy can be studied, unless aided by chemical science.

The atmosphere, the earth, the ocean, you need not be told, are necessarily very interesting to us.

The atmosphere is the region of elastic fluids, that is, of all airs or gases which are not condensed at the ordinary degrees of temperature or of heat to the action of which they are exposed.

The earth is that solid part of our globe formed of diverse materials, which at ordinary degrees of heat are neither liquefied nor rendered gaseous,

or, in other words, are neither converted into fluids nor elastic fluids.

The ocean is that portion which, under the same circumstances of temperature, neither becomes solid or aeriform, but remains constantly and uniformly liquid.

These, the three great regions of the planet we inhabit, though so strongly marked asunder, so different and distinct, are yet intimately connected, and administer to each other in a marvellous manner. Exhalations are constantly ascending from the earth and ocean into the atmosphere. From the atmosphere almost as constantly there is returned to the earth and the ocean, the matter of these exhalations condensed either in the liquid or solid form. The same causes are always acting, and, acting on the same materials, though infinitely varied, an extraordinary uniformity of effect is produced, and a constancy of condition preserved in the atmosphere, on the surface of the earth, and in the ocean, rendering each of them fit for the great part it has to perform in the economy of nature. The later and the earlier rains, perennial springs and streams, the trade winds and monsoons, the regularity of seasons, spring time and harvest, the exact line of demarcation on our coasts between the earth and ocean, are proofs demonstrative of the constancy of condition just referred to.

It is true that occasionally there is an interruption to this harmony of order: a hurricane may occur here; a season of drought there; in one spot a volcanic eruption; in another a deluge of rain, a destructive fall of hail, or an inroad of the sea. These are the exceptions to the general rule, depending on the operation either of extraordinary causes brought into action, or of ordinary ones acting with unusual intensity; and are, as such, well adapted to make us admire the more the regular order and harmony which commonly prevail.

The atmosphere, though formed of every thing permanently elastic or aeriform belonging to our globe, or capable of becoming aeriform on passing into the state of vapour at ordinary temperatures, though, therefore, an exceedingly miscellaneous mixture, yet, as regards its principal ingredients, it may be said to be quite the contrary. The numerous ingredients which must exist in it, are so minute in quantity, that few of them are appreciable; and those which are appreciable readily, are limited to a very small number, viz. two gases, simple substances, oxygen and azote; one gas a compound, carbonic acid; and another, commonly called vapour, but really a gas, also a compound, viz. water in its elastic state. The existence of these, the principal ingredients of the atmospheric mixture, are easily demonstrated.

1st. *Of the aqueous part.*—There are certain acid gases or airs which have a powerful attraction for water, and which, by combining with a portion of water, become liquid, and from invisible become visible, from being so condensed. Muriatic acid gas is one of these. This bottle is full of muriatic acid gas; on taking out the stopper, you will perceive how fumes will be produced when the gas mingles with the air. These fumes are the liquid acid formed by the union of the gas with the moisture in the air.

There are certain salts which have a powerful attraction for water, and which, in combining with it, become liquid, or deliquesce. Common salt is one of these. If kept in air, over water, it soon becomes liquid. If kept exposed to the atmosphere, its condition, as to moisture, will be constantly varying according to the quantity of water, in its gaseous state, in the atmosphere: when little, it will appear dry; when a moderate quantity, it will appear damp; and when in an unusual quantity, it will be in a deliquescent state. Chloride of calcium has a more powerful attraction for water than chloride of sodium or common salt; however little water may exist in the atmosphere, this salt, on exposure, becomes liquid. I shall spread some of it in powder on a plate; you will presently see it deliquesce.

All animal and vegetable substances attract

water, and, being in a manner measures of the degree of moisture in the atmosphere, are called hygrometrical. If you dry thoroughly a cord made either of cotton, or flax, or hair, or animal fibre, such as catgut, by placing it before a fire, you will find it will lose weight and will become longer owing to the loss of moisture; and, on the contrary, if you expose it to the atmosphere, in proportion to the quantity of aqueous gas present, it will gain weight and contract lengthwise, becoming at the same time thicker. An experiment, the making of which will occupy very little time, may answer well to illustrate the fact. Here is a dry cord, dried by having been kept in a jar with a substance that attracts moisture powerfully — quicklime. You see its length as it is extended. I shall now wet it. You see now, when extended, how much it is shortened.

Further, if we take a glass tube, say 29 inches in length, and fill it with mercury, and place it perpendicularly, inverted in mercury, there will be no fall of the liquid metal; this column is supported by the pressure of the incumbent atmosphere. Now, if a drop of water be admitted, there will be a slight fall of the mercury, owing to a portion of the water being converted into vapour, or, to speak more correctly, into gas, which, by its elastic power, is capable of counteracting a certain degree of pressure from the atmosphere without.

2dly. *Of the carbonic acid part.*—Certain substances have also a strong attraction for this acid. Lime is one of them, that is, the compound of the metal calcium and oxygen. If lime be exposed to the atmosphere, it first absorbs moisture from the atmosphere, nearly one third of its weight, and then appears as a dry powder—the quenched lime of the mason, the hydrate of the chemist. If it be further exposed to the atmosphere, it draws carbonic acid from it, becomes a carbonate of lime, and at the same time loses the water with which it had previously combined. This carbonate is identical with limestone and marble; and lime (quicklime) is obtained from limestone and marble merely by the expulsion of its carbonic acid by the strong heat of the lime-kiln. Hydrate of lime is slightly soluble in water. If this solution be exposed to the atmosphere, in a short time a pellicle or crust will form on it, which on examination will be found to be carbonate of lime. I shall pour into this vessel some perfectly transparent lime water; in a little while the crust mentioned will begin to appear.

There is a form of apparatus before you which is well adapted, not only for demonstrating the presence of carbonic acid in the atmosphere, but also for determining its proportional quantity. It consists, you perceive, of a bottle with two mouths, provided with stop-cocks, to one of which

is attached a slender bent tube, to the other a perpendicular one ending in a globe. By means of it, lime water, or milk of lime, or solution of potash, which also has a strong attraction for carbonic acid, can be made to act on a measured quantity of atmospheric air, and the quantity of carbonic acid gas in the air will be denoted by the rise of the water in the bent tube, precautions to prevent change of temperature during the trial being observed.

3dly. *Of the oxygen and azote portion of the atmosphere.* — When lead or mercury in a close vessel is kept at a certain temperature for a considerable time, it combines with the oxygen of the air, and become converted into a red powder. That from mercury was long known by the name of red precipitate *per se,* no substance between it and the atmospheric air being concerned; that from the lead was also long known, and under the name of minium. If either of these oxides, or compounds of metal and oxygen, be strongly heated, it will be decomposed. In the instance of that of mercury, the metal will be revived, and all the oxygen absorbed will be recovered; in the instance of that of the lead, only a portion of the oxygen will be expelled, the metal will remain in a lower degree of oxidation, viz. that of litharge. It would occupy too much time to illustrate what I have stated by experiments; I mention the

facts because, in the history of chemical science, they are most important. It was from precipitate *per se* that oxygen was first obtained by Dr. Priestley, and its discovery made. The experiments I have described were *experimenta crucis*, by which it may be said, the foundations of the modern science of chemistry were laid,—that science which is exact, the expression mainly of facts, and not of speculative views, such as was the older science, though it hardly deserved the name of science, which it superseded.

There is a gas called the nitrous gas, a compound of azote or nitrogen and oxygen in certain proportions. This gas is capable of combining with more oxygen, and in so doing it is converted into a powerful acid; and that acid, which is also a gas, having a strong attraction for water, if it be allowed to mingle with the atmosphere, produces fumes, the acid being condensed into a liquid. Here, in this vessel, is a portion of nitrous gas; in this other is a portion of atmospheric air, an equal volume. On admixture, you will perceive, a red vapour will be produced, and fumes, there being moisture in both, and that the water will rapidly rise, owing to the removal or separation of the oxygen.

Phosphorus, it has been shown to you more than once, burns with intense vividness in oxygen gas. The compound formed is a solid acid, the

phosphoric. It burns, too, you have seen, with a bright flame in atmospheric air, when this same compound results. In consequence of its forming, in combustion, this compound, and in consequence of its very powerful attraction for oxygen, owing to which it is capable of separating the whole of the oxygen from a mixture, such as that of common air, it is particularly fitted for the purpose of demonstrating what we have now under consideration, viz. the presence of oxygen in the atmosphere in admixture with azote.

I shall make before you an experiment which you have witnessed before, which is, the burning of a portion of phosphorus in air confined over water in a retort. You will perceive, after the combustion is over, and the retort has cooled to the temperature of the atmosphere, that the water will rise in the neck of the vessel, denoting thereby the abstraction and proportion of the oxygen consumed, and *that* the whole of the oxygen present. You will perceive, too, how large is the quantity of air, of azote, which is residual, compared with that of the oxygen which has been removed.

According to the most accurate researches that have been made on the composition of the atmosphere, the two first ingredients mentioned, the water and the carbonic acid, are in variable proportions; the oxygen and azote in proportions

almost, if not quite, invariable. The watery part, as to quantity, is chiefly determined by temperature. The warmer the atmosphere is, *cæteris paribus*, the more of aqueous gas is present in it: it abounds, consequently, in the tropical atmosphere; and, on the contrary, in the arctic, in winter, it exists hardly in an appreciable quantity. Within the tropics, however dry the weather, if any article of dress, whether of cotton, silk, or linen, be brought near a fire, it will apparently smoke, from the expulsion of moisture. But not so within the arctic regions in the depth of winter, when the temperature of the atmosphere may be 50 or 60 degrees below the freezing point of water. I have been assured by a northern traveller, that under such circumstances, he has seen a blanket dried in the open air, after having been washed and frozen, — dried by the evaporation of ice — not affording any indication of moisture remaining in it when brought near a fire, no visible vapour whatever rising from it.

I have stated that the proportion of aqueous gas in the atmosphere is chiefly determined by temperature. With the barometer tube holding mercury, to which a little water has been added, this is easily shown: the higher the temperature is raised, the more aqueous gas will be generated, the more the mercury will fall; and, at the boiling point of water, the tube will be entirely

filled with aqueous gas or steam, water at this temperature, viz. 212°, under ordinary atmospheric pressure, being a permanently elastic fluid.

As, *cæteris paribus*, it is the temperature which determines the proportion of moisture or aqueous gas in the atmosphere, it is necessarily high within the tropics, and, especially near and over the sea, and in situations not subject to the action of parching winds, rendered excessively dry by blowing over heated, arid deserts. From such observations as I have made in this island, I am led to infer that the quantity of aqueous vapour in 1000 parts of atmospheric air is often as much as 30, and seldom less than 23 estimating by volume; or by weight, in one instance it will amount to nearly 10 grains of water in the cubic foot of air, in the other to a little less than 7 grains, which denote an average at least double that of the climate of England.

The proportion of carbonic acid in the atmosphere, judging from the few and very limited accurate experiments that have yet been made—limited, I mean, as to country—is far less variable than that of the aqueous portion, ranging from about 3 in 10,000 of air to nearly 6, and seemingly connected more with peculiarities of locality than with temperature of the atmosphere: thus it has been found in the atmosphere of towns in a

little larger proportion than in the air of the country; in a rather less proportion in the air over large surfaces of water than in that over a cultivated country; and, also, in rather less proportion in the atmosphere after rains than before them. The extent, however, of variation, as hitherto ascertained, has not exceeded 2 parts in 10,000.

The proportions of oxygen and azote in the atmosphere, it has already been stated, are almost, if not quite, invariable; and, what is very remarkable, they are so according to the most accurate experiments that have yet been made, whether the air examined has been taken from the summits of the highest mountains, from the level of the sea, from the streets of the crowded city, from the wards of an hospital, or from the open country. The proportion of one gas to the other has been found to be in volume as 21 to 79; 21 of oxygen, 79 of azote.

Considering that in all climates, at all seasons, in all situations, these are the proportions in which these gases have been found to exist in the atmosphere, it is not surprising that the inference was drawn that they are united chemically, and that a certain chemical attraction is the cause of their being in these seemingly definite proportions. This view, plausible as it was, does not appear to be true; and it is now universally re-

linquished by all exact inquirers. The conclusion they have arrived at is, that the oxygen and the azote, as well as the carbonic acid gas and the aqueous gas, are merely in a state of mechanical mixture; that most intimate indeed, but partaking no wise of the character of chemical union. This view does not lessen our feeling of admiration at the composition of the atmosphere; it rather increases it, reflecting on the immensity of space over which it extends, and whilst enveloping the whole of our globe, reaching above its surface to a height of many miles, not less, it is presumed, than fifty, and yet every where, and always, as regards its principal elements, the same.

This is a wonder, indeed; and it may be well to pause briefly, and notice some of the circumstances to which this extraordinary uniformity of mixture is to be attributed. If we introduce into a vessel, over water, equal volumes of the lightest and of the heaviest of the gases, for instance, hydrogen and carbonic acid, and examine the contents after a little while, taking a portion from the upper and another portion from the lower part, we shall not find the hydrogen accumulated where it might have been expected from its lightness, nor the carbonic acid where it might have been expected from its greater weight, the one towards the top, the other towards the bottom, but throughout, at top, bottom, and middle, we

shall find them equally mixed. Again, if we fill two vessels with the same gases, and connect the vessels by means of stop-cocks, on opening the communication between the two vessels by turning the stop-cocks, supposing the hydrogen to be in the upper and the carbonic acid gas in the lower vessel, the two gases will not continue apart; rapidly through the narrow opening there will be a descent of the lighter hydrogen gas, and an ascent of the heavier carbonic acid gas, till the two are equally mixed. And the same results would take place, the same equable commingling of the particles of the light and heavy gas would be effected, were the two vessels separated by an animal membrane, such as bladder, or were the orifices of the stop-cocks filled with plaster of Paris, both being pervious to air.

This commingling is accompanied by no condensation, no change of volume. The particles of one air, judging from effects, have been considered as repulsive of each other, and indifferent or inert as to the particles of any other air with which they do not combine chemically; and to this the rapidity of gaseous diffusion is attributed, one kind spreading through another kind as if rushing into a vacuum, and with accelerated force and rapidity from the similar particles repelling each other.

That this principle of gaseous diffusion is

intimately connected with the uniformity of mixture of the several ingredients of the atmosphere cannot be doubted. Other causes are likewise in operation conducive to the same admirable effect. The motion of our globe rapidly revolving may be considered one of them; and connected with its motion, and with its place in relation to the sun, the transition from day to night, and the changes in the seasons of the year, productive of changes of temperature in the atmosphere; and these changes productive again of perpetual motion of its parts, giving rise to currents of air in various directions — the breeze, the gale, the hurricane — all having the same tendency to aid diffusion and produce that uniform mixture which has been found to exist. The manner in which volcanic ashes, or the dust of the desert — the one projected by volcanic eruption, the other raised, it is probable, by a whirlwind — are scattered over an immense space, hundreds of miles of surface, as has often occurred, may aid in forming an idea of the diffusive power of the winds; the winds themselves being the matter of the atmosphere, those invisible elastic fluids in the act of change of place and diffusion.

This tendency to intimate mixture of the main ingredients of the atmosphere, depending on their own qualities, and those other causes in constant operation aiding, may be mentioned as

one of the reasons, that the innumerable exhalations from the earth's surface of all things volatile, from the aroma of a flower to the offensive effluvia arising from a decaying animal or vegetable, are hardly any of them appreciable, using the most delicate and searching methods of inquiry that have hitherto been employed.

Another reason is, that there is, as it were, a special cause preventing their accumulation in the atmosphere. This is rain, which, as it passes through the air, washes it, and brings down with it the larger number of all the exhalations alluded to, thus purifying the atmosphere in the simplest and most efficacious manner, and rendering it fit, without interruption, for the important uses for which it is designed. If rain water be carefully examined, proof will be obtained that it performs this purifying function. It will be itself found never pure. If examined for the volatile alkali, a substance that is evolved whenever animal matter decomposes, it has always been detected, at least in Europe; and I have obtained traces of it in rain that fell in this island, but so feeble, that I am induced to infer that there is less of this substance in the atmosphere of the West Indies than in that of England, or of the continent of Europe. If vegetable matter be sought for in rain water, it also, in exceedingly minute quantity, may be detected, and saline matter likewise; and a free

volatile acid, the muriatic, has been discovered in it.

Regarding merely the composition of the atmosphere as a mechanical mixture, its uniformity is sufficiently marvellous. When we consider the uses to which it is subservient, the great and varied part it performs in the economy of nature, this constancy appears the more remarkable, and especially in connection with the effects or phenomena with which it is concerned, and the fine compensating powers which act in their production.

The atmosphere, permeated by rays of heat and of light from the sun, is, directly or indirectly, the material cause of all that animation which we witness around us. Every animal that breathes, every plant that vegetates, every fire that is kindled, every rock that decomposes, — in brief, every change we witness, is effected through the instrumentality of this wonderful medium. The ceasing to respire, and death, are synonymous; the exclusion of air, and the extinction of flame, are simultaneous; so, too, is the exclusion of air and the cessation of chemical change in animal, vegetable, and mineral substances, — with some few exceptions. In brief, without an atmosphere to our globe, such as it possesses, it would be a most dreary waste of rock and water, — a lifeless desert; and for all time, according to our present

knowledge, it would so continue, excepting, indeed, the little variety that might be produced by the occasional outbreak of a volcano, or the convulsion of an earthquake, depending on internal causes in operation nowise connected with the atmosphere.

How different from this horrid imagined scene is that which really exists! Wherever we cast our eyes, whether along the surface of the earth, over the sea, or upwards to the sky, there is this impression made, — that the nature by which we are surrounded is always active, and in ceaseless change; and that this activity and change are connected with organisation and life, which are, indeed, the strongest manifestations of them. Scarcely a spot that the eye can reach that is without living beings, vegetable and animal. The surface of the rock, apparently destitute of soil, possesses them. They are to be found even amongst Alpine snows and Polar ice. More than 50,000 distinct species of insects have been described by the naturalist; and about twice as many separate species of plants; and almost every day additions are made, and it is probable will for a long time be made, to a number already so immense. Besides what are visible to the naked eye, there are millions, countless living beings existing which, from their minuteness, escape detection by the sharpest unaided vision, and can be discovered

only by the magnifying power of the microscope, an instrument which has brought as many wonders to light, as regards the minute works of creation around us, as the telescope has in relation to the great masses of matter which are distributed through ethereal space; and the more improved the former instrument is rendered, — as is also the case with the telescope, — the more numerous and surprising are the disclosures which it makes, tending even to prove that the invisible species — that is, visible only by aid of the microscope — are not fewer in number than those which from their large size require no such help to be seen, and rendering it, indeed, probable that the invisible exceed the visible in the number of their species. *This*, too, is well deserving of being kept in mind, — that there is no confusion of species, no appearance of imperfection in the smallest visible animalcule. And further, that though there is a gradation from the simplest form of living being, from the nucleated cell, from the monad to man, the gradation is by distinct species; not, as it were, an ascent by a continuously inclined plane, but by a succession of steps, so as no wise to favour the notion formed by some materialists, that there is in matter a property by the existence of which, under favourable circumstances, one species of an inferior kind can become another of a superior, and so in process of

time, by a gradual elaboration of organs, the simplest form of life may become the most complicated, and man may be traced back to the invisible monad.

I shall now, with your leave, make some mention — it must be brief, and it will be very imperfect — of the part performed by the several ingredients of the atmosphere in the economy of nature, constituting that active and animated scene around us to which I have just alluded.

1st. *Of the aqueous part,* — to observe the same order as that which has hitherto been followed.

The aqueous vapour in the atmosphere is the immediate source of clouds and mists, of rain, hail, snow, and dew, and appears to be concerned in the production of atmospheric electricity, whether witnessed in the thunder-storm in its state of greatest intensity, or in a milder degree in the harmless coruscations and flashes of light which are occasionally seen passing from cloud to cloud.

Rain, hail, and snow are the results of an excess of moisture in the atmosphere, and have the effect of unloading it of that excess, and seem invariably in their production to be accompanied by a fall of temperature, which in the instance of rain in hot climates generally, and of hail in some of them, is so agreeably felt and is so refreshing. Dew, too, is owing to reduction of temperature, but not

in the atmosphere so much as in the substances, chiefly the leaves of low plants, on which it forms — not falls — a cooling of them occasioned by the radiation of heat from them through the clear air into ethereal space. Clouds and mists have their origin in the same cause — a lowering of temperature, being floating particles of water so condensed; but whether collected into excessively minute drops and suspended in consequence of their fineness, or so arranged as to form little bladders or vesicles, is hardly yet determined in a satisfactory manner.

All the beauty of the sky—so varied and charming, from the rainbow that occasionally spans, and the gorgeous clouds that so often adorn it, to its ordinary colour, the cerulean hue, its characteristic — is due to this aqueous part in its different states. Were the sky without moisture, it may be inferred its aspect would be most dismal — an intense black. The higher a traveller ascends a lofty mountain, the darker the aerial hue becomes. And blue, we know, is the colour of water, whether liquid or solid, — whether witnessed in the great mass of the waters of the ocean, or in that of the glacier. We may, therefore, I think, fairly conclude (at least as probable), that the beautiful blue of the sky is not the colour of either oxygen, azote, or carbonic acid, but solely that of the aqueous ingredient.

The usefulness of this aqueous portion, exclusive altogether of the beauty it imparts, is hardly to be described, it is so great and varied. Neither animal nor vegetable life could exist without moisture in the atmosphere, and derived from it. Its absence would be as fatal as the annihilation, were it possible, of all the other ingredients, not excepting the vital air, or oxygen. It would be easy to prove this by reference to facts; but I must not attempt to give the proof,—time is wanting for so doing. You know here, from too often acquired experience, that drought arrests the progress of vegetation; and that a supply of moisture to your fields in successive showers is essential to their fertility. *Cæteris paribus*, the skilled planter here can calculate almost to a nicety the amount of his staple crop — the sugar cane — if informed of the quantity of rain that has fallen between the planting of it and its reaping, and the intervals between, and the character of, the showers. But, let me add, the fertilising effect of rain is not simply owing to the moisture supplied; it is due also to other elements of fertility — the gases, oxygen, azote, and carbonic acid, with which the rain-drop is impregnated, and also to the saline matter, however minute, which it holds in solution, acquired in its descent.

2ndly. *Of the carbonic acid.* — Small in quantity as this is in comparison with the other ingredients

of the atmosphere, it is, when strictly considered, hardly less important, even confining the view of its use to the support of vegetable existences, and through them to that of animals. This gas, indeed, with water, may be held to be the special food of plants. The green leaf possesses this remarkable property — that of decomposing carbonic acid under the influence of light, retaining the carbon to be assimilated and afford material to the growth of the plant, extricating at the same time the other element of the acid, its oxygen, which, becoming free, returns into the atmosphere, there to perform its part. This is applicable to the whole of the vegetable kingdom, and at all times whilst the sun is above the horizon, and whilst vegetation is active, as denoted by the freshness of leaf. It is easily illustrated by experiment. If you plunge under water — it should be rain water — any fresh green leaf, and expose it to sunshine, you will presently see small bubbles of air adhering to its surface, or rising from it; and if you make the experiment under an inverted glass vessel full of water, and collect the air disengaged, you will find that it will have the properties of oxygen. Farther, if you take a small plant, and put it under a bell-glass or a tumbler, and supply it with water containing carbonic acid, though it may rest on an artificial soil of sulphur, or fine sand, or pounded glass, the plant will

throw out leaves and increase in size and in substance. If you examine it, it will be found to have gained weight; and if it be analysed, that weight will be proved to be in part the result of the carbon added to it; and if the air in the glass vessel be examined, it will be found to be enriched with oxygen. In all native forests, we have the most striking proof of this power, inherent in the leaf, of separating carbon and oxygen. In the trees of such a forest how enormous is the quantity of carbon thus derived and accumulated; and clearly from the atmosphere, inasmuch as the soil of the forest is not impoverished, but is enriched in vegetable and carbonaceous matter, and this in proportion to the age and size of the trees, every leaf that falls occasioning an increase.

The manner in which, through the medium of vegetables, carbonic acid administers to the support of animals, is obvious on reflection, inasmuch as without vegetables for food all the different races of animals must perish, — first, those which live entirely on vegetables, and, last, those which are solely carnivorous, there being no substitute to support either the one or the other.

3rdly. *Of the oxygen and azote.* — Of these two parts, the azote, which has commonly little attention given to it, is not to be held as a mere diluent of the oxygen, but is to be viewed as an important active part, without which the atmo-

sphere would be inadequate to accomplish all its effects.

Certain mixtures of earths, in which a little potash is present, on exposure to the atmosphere, are productive of nitre, that is, a compound of nitric acid and potash, — the nitric acid itself — a compound of azote and oxygen, both of them derived from the atmosphere.

A large number of plants yield products containing azotised substances. Such is wheat, in which is gluten; such are rice, Indian corn, the common and the sweet potato, the pea, and bean: in brief, all the kinds of grain that are used for food; the different kinds of pulse; the different kinds of roots; in which, in all, without exception, gluten exists, or an analogous compound. These, too, either directly or indirectly, would appear, like nitre, to obtain the azote necessary to form the azotised compounds alluded to from the atmosphere. And when I remind you that it is from these azotised compounds in vegetables that animals feeding on them derive the material of their most important organs, almost by a kind of transfer, with slight modifications *in transitu*, you will perceive how important is the azote ingredient of the atmosphere in relation to vegetable and animal organisation.

The oxygen portion of the atmosphere has fixed the attention of inquirers, and deservedly so; I

will not say on account of its pre-eminent importance in the economy of nature—all the other ingredients rivalling it in importance—but for the many striking effects with which it is associated, and which may be referred to it as a cause.

You have seen how the flame of a burning body is extinguished on the consumption of a certain portion of the oxygen of the atmospheric air in which the burning body was immersed. You know how essential the oxygen of the air is to respiration, and respiration to animal life. If the function is arrested for the short space of three minutes in the instance of man, whether by the exclusion of oxygen by stopping the air passages, or by the abstraction of the oxygen from the admixture with azote, the result is the same—death. No fermentation takes place, all other circumstances favouring, if oxygen be entirely excluded; nor does dead animal matter putrefy, or vegetable matter decompose, or rocks disintegrate to form soils, unless oxygen be present, however favourable all other circumstances may be. It is not, therefore, surprising that it should be called vital air—the great supporter of combustion—the acidifying principle, and be considered the principle most concerned in all the ordinary metamorphoses of matter, whether connected with decay or putrefaction, decomposition, or disintegration. Many of these changes are analogous. In all of them

there is reason to believe that heat is evolved. It is remarkably so where either animal or vegetable matter is concerned. In them this production of heat is connected with the formation of carbonic acid gas. When animal matter putrefies, this gas is disengaged, and with it more or less of ammonia. The same happens when vegetable matters decompose containing azote. If they contain no azote, then, in fermenting, they yield little else than carbonic acid. This gas, too, results from their combustion. It results too from the respiration of animals; and in proportion to the quantity formed is the degree of heat imparted to the animal body; and this without exception, however the function of respiration may be performed in the different orders of animals, whether by means of lungs, gills, tracheæ, or without special apparatus for the purpose.

The tendency of all these changes — of combustion, of animal respiration, of fermentation, of the decomposition of dead animal and vegetable matter, of the formation of soils from rocks,— their general tendency is of a deteriorating kind as to the atmosphere—to abstract its oxygen, or to convert it into carbonic acid.

The tendency of plants, through the medium of their green leaves, aided by the sun's light, is, we have seen, to decompose carbonic acid, detach and appropriate its carbon, and liberate its oxygen;

exercising thus an influence, and producing an effect, the opposite of the preceding.

Thus, not only the vegetable performs the part of supporting the animal, but the animal performs the same part to the vegetable; the death of the one contributing to the life of the other, and, at the same time, to the maintenance of a uniform condition of atmosphere in all climates, and in all countries, such as the economy of nature requires, and assuredly strongly demonstrative of the wisdom by which this economy is regulated. And, let me add, the more narrowly it is looked into and scrutinised, the more admirable will that economy appear, in the fitness of means to ends—in the antagonist and compensating powers concerned — in the complication of causes and simplicity of effects — and in the wonderful harmony prevailing throughout; a harmony which may be well called divine, and be held to be demonstrative of a ruling or ordering Power that cannot be less than Divine. I have said, the more searching is our scrutiny the more we shall find of this divine harmony and order. May I adduce one or two instances more? The light of the sun, the sacred light, as of old it was well called, which enables us to see, is the cause of all the colours which impart beauty to the earth's surface: the green of the leaf, the verdure of the meadow and forest, the most grateful of colours, is intimately connected with the

power of the leaf to separate oxygen from carbonic acid; the means, we have seen, of preserving the just composition of the atmosphere. The air which enables us to hear, put into motion by vibrations communicated to it, is the immediate cause of all the sounds we perceive, constituting the wonderful and infinitely varied language of animated and inanimate nature: the same elastic medium that receives and transmits the impulse from the vocal organs of a singing bird, supports the same bird in its flight, and carries it with the speed of the wind in its distant migrations. Moreover, the structure of the bird and its functions are in like perfect accordance with the medium it moves through and its habits of life. Its temperature is higher than that of any other race of animals; and this in consequence of its greater consumption of oxygen, — partly owing to the manner in which air permeates its frame, being received even into its bones, so rendering its frame whilst warmer also lighter and fitter for flight,—and partly owing to its greater energy of muscle, occasioning a more rapid circulation of the blood; whilst this greater muscular power equally fits it for vigorous and enduring flights. Similar remarks apply to the other inhabitants of the air. The insect, when at rest, is cold; the air with which it is penetrated is in a manner condensed, and its consumption trifling; but when

it is roused to exertion and takes wing, its respiration becomes active, its temperature rises rapidly, so rendering the body lighter by the expansion of the air within it; and at the same time, it may be inferred, owing to the greater consumption of air, imparting increased muscular energy, fitting it for, and rendering it equal to, the exertion it is then making. Beautiful as are these demonstrations of wisdom of design, the like are so numerous, that were they to be dwelt on at any length they might even satiate and fatigue:—even in this way illustrating the limited and imperfect nature of *our* faculties, in comparison with that perfection of wisdom and of power indicated in the objects on which they are employed.

LECTURE III.

ON THE EARTH.

The solid earth, like the aerial atmosphere, is not, as the ancients supposed, formed of one elementary substance, but of very many such substances; indeed, all the different elements which chemical research, in recent times, has made us acquainted with, — in number, at present, sixty-two, — enter into its composition.

When we consider the nature of these diverse elements, there is no difficulty in comprehending how this should be.

Of these sixty-two elements, or simple substances, two only, viz. oxygen and azote, occur in nature uncombined, and in the state of permanently elastic fluids; and these, we have seen, are the principal constituents of the atmosphere.

Further, of the whole class of simple substances, other two only, viz. hydrogen and chlorine, are gaseous at ordinary temperatures; but these have never been detected existing in nature uncombined. One of them, hydrogen, most commonly occurs in union with oxygen, forming water; the

other, chlorine, most commonly combined with the metal sodium, constituting common salt: the two main ingredients of the ocean.

Farther, of the whole class of simple substances, two only are fluid at ordinary temperatures. These two are mercury and bromine; the first of which only has been met with uncombined, and then included in solid rock.

The other elementary bodies, amounting to fifty-six, comprising one that is doubtful, are all in their natural state solid, that is, at the ordinary temperature of the atmosphere; and even at its maximum temperature, in the hottest regions at the surface of our globe, are incapable of becoming either liquid or gaseous, and consequently are essentially elements of the earth.

The doubtful elementary substance just alluded to, is fluorine; and it is so in consequence of all the attempts hitherto made to insulate it having been unsuccessful, and that owing to its extraordinary disposition to combine, so that it is no sooner detached from one substance than it unites with another. It most commonly occurs in nature combined with calcium, constituting the well-known mineral, fluor spar.

Of all these various ingredients of the earth, there is this peculiarity in relation to them, and which, perhaps, might be anticipated *à priori*, viz. that the great majority of them are in a state of

combination. Few, very few, exist simple or pure. Most of them are so combined as to form mineral species, of which many hundreds are well defined as distinct chemical compounds, constant in the proportions of their parts, and possessed invariably of the same properties, and commonly occurring under the same forms; and these invariably included in straight lines, capable of being measured, and as it were geometrical, and not in curved lines, such as we witness in the greater number of organised beings, whether of the animal or vegetable kingdom.

The few simple substances alluded to as existing in the earth, that is, in its crust, for of its interior we are altogether ignorant, may be comprised in two which are inflammable, and in five that are metallic. Carbon or the diamond, and sulphur are the inflammable substances; gold, platinum, silver, mercury, and copper are the metals, omitting three or four alloys of other metals of rare occurrence, and, excepting in their scientific relations, of little importance or interest.

That there should be so few bodies found uncombined is not surprising. And yet the circumstance, the fact of their paucity, is well deserving of consideration. How, it may be asked, is it, that these substances having an attraction for, a disposition to unite with others, have not so united, have remained apart, as if under the im-

pulse of repulsion, in the midst of elements we know they are capable of combining with? Take, for instance, the metal copper; it is not uncommon to find in the same vein, close together, this metal in union with sulphur, either alone or with iron; in union with oxygen; and also free or uncombined. Now, it can hardly be supposed that so common an element as oxygen could have been deficient. The presence, then, of the uncombined copper, in the supposed instance, seems to denote that powers have been, and may still be, in operation in nature, capable of overcoming chemical attraction; and that the existence of the substances, few in number, specified, uncombined, surrounded by mineral compounds, is owing to the interference of such powers, and a proof of their having operated.

Of the large number of mineral species which constitute the chief portion of the crust of the globe, some are binary compounds of two elements: such is silica, which is so abundant; such is alumine, which is also abundant; such is oxide of iron, which is almost everywhere diffused; and such are the metallic oxides generally, and the chlorides generally, and all the compounds known of the metals and sulphur. Others are binary compounds of binary compounds, and, consequently, containing four elements. Limestone and marble, so abundant on the earth, are ex-

amples of this composition, consisting, as they do, of lime and carbonic acid: lime, a compound of the metal calcium and oxygen; carbonic acid, a compound of carbon and oxygen. Gypsum is another example, it being composed in its anhydrous state of lime and sulphuric acid, and this acid, as you are probably aware, consisting of sulphur and oxygen. Others, again, are still more compounded, containing more than four elements; but whether combined according to the binary rule, if I may use the expression, or in a different manner, has hardly yet been determined. These very compounded bodies constitute an important order of minerals, such as felspar, mica, hornblende, and others, into the composition of which commonly lime, magnesia, alumine, and silica enter, and also an alkali. These minerals are generally found to occur in a crystalline state, and often mixed together, forming compound crystalline rocks, such as granite, porphyry, serpentine, basalt. Considering these compound minerals, the same question may be asked as the preceding,—How is it that simple binary combinations of elements exist, such as silica and alumine, surrounded by other bodies with which there is a natural tendency for them to combine and form the complex binary compounds? The answer, I believe, to this question, must be like that before given, viz. that the

occurrence is owing to, and is proof of, an interfering power, the antagonist of chemical attraction.

Transferring our attention from the constituent elements of the solid crust of our globe to this crust itself, on examining it, we are not only struck with its irregularities of surface — here rising into mountains, there sinking into valleys, or extended widely into plains — but we are also impressed with the great variety that is displayed in the structure of those of which there are natural sections, as in sea and inland cliffs and precipices, or cuttings made by art, such as occur in quarries and mines. In some countries, in such situations, we find a uniform crystalline rock, without any traces of organic remains, and without any distinct appearance of stratification. Near it we may observe another kind of rock, less distinctly crystalline, of a foliated texture, bearing some marks of stratification, but without any vestiges of the remains of animals. Near this we may meet with a rock very different from either of the preceding, being not crystalline in its structure, composed of layers or successive strata, and these commonly highly inclined, rarely containing any visible organic remains, but if closely inspected found to consist of particles or minute fragments, of such a kind as to denote that they have been derived from other rocks.

In certain of these rocks, when explored, veins are found to occur rich in metallic ores. In some of them, disseminated through their substance, widely scattered, may be detected, on diligent search, the Oriental gems—the sapphire, the ruby, the topaz; and, in some, native metals, especially gold. Whilst in others are found beds of anthracite, or native coke; and more rarely plumbago, the latter in veins or scattered particles.

Extending our inquiry to other countries, we find many varieties of rock, varying not only in their physical qualities, but also in the nature of their chemical elements: some consisting chiefly of siliceous matter, in the form of sandstone; some chiefly of calcareous matter, in the form of chalk, limestone, and freestone; some chiefly of aluminous matter, in the form of shale and varieties of slate. Various as these are and differing, there are certain circumstances common to all of them: thus they are not crystalline in their texture; they are regularly stratified, their strata generally little inclined, and they contain organic remains. These remains are deserving of particular attention, differing as they do in their species, according to the kind of rock in which they occur. In rock of one kind they consist chiefly of extinct species; that is, of species of animals not known at present to be in

existence alive, and of which, were it not for their *reliquia*, we should be entirely ignorant. In rock of another kind, the remains are principally of extinct species. In a third kind of rock, a mixture is found of extinct and existing species; whilst in a fourth the remains which are met with are almost entirely, if not altogether, of species now known to be living. Associated with some of these rocks are often beds of coal and clay-iron ore; and in the former are commonly found impressions of plants, indicative of the vegetable origin of coal. And this coal, it is worthy of remark, is commonly bituminous, burning with flame, and greatly different from the anthracite coal before mentioned, hardly less than it differs from the diamond, the most beautiful and the hardest of minerals.

Extending our inquiries farther and to other countries, we shall see vast plains totally destitute of rock, bordering on the sea and little raised above its level. If rivers flow through them with deep beds and steep banks, as commonly happens, affording an opportunity to become acquainted with the nature of the ground, we shall find that that of which these countries consist is composed chiefly of clays and sand, in which are often found buried portions of trees or deposits of vegetable matter, of a peaty carbonaceous quality, little different from coal such as lignite,

and in which are also occasionally discovered, similarly interred and preserved, the skeletons of the larger animals, —animals no longer to be met with excepting in distant regions, or lost altogether as living species.

It is very worthy of notice, and of being kept in mind, that neither in the situation last mentioned, nor in any of the preceding, where organic remains have been observed, have any vestiges yet been detected of the remains of man, excluding certain exceptional spots, in which their occurrence, there is ground for belief, may be easily explained on the supposition of their being of comparatively recent date and of historic periods.

Further extending our observations, we shall perceive common to all countries of which mention has been made, that is, where naked rock does not arise to the surface, a superficial layer or bed of matter of a peculiar kind, so well known as soil, the support of the vegetable kingdom, and so important to us in consequence; and which is formed generally of very mixed ingredients, in a comminuted state, chiefly mineral, variously derived, but never, when fertile, entirely destitute of animal and more especially of vegetable matter, either decomposed or decomposing.

The several kinds of rock and of rocky matter which I have thus brought to your notice as

offering themselves to view in different countries, may occur in the same country, and in a small district of country, if it be of a mountainous character. The summits of the mountains may consist of crystalline rock, or of rock of an obscurely crystalline structure, having incumbent on their sides slaty rocks highly inclined; and lower down, also incumbent on them, stratified rocks, containing organic remains, the strata of which are either less inclined than the preceding, or quite horizontal; and lower still, constituting the bed of the mountain valley, deposits of clay and sand. Instances of the kind are not uncommon. Nor are instances of a contrary kind uncommon, especially as witnessed in islands far apart in the ocean. One island may be formed entirely of crystalline rock; another of that which is obscurely crystalline; and a third and fourth of stratified rocks, either with or without organic remains. Why, it may be asked, is there such variety, such order, and at the same time such apparent want of order, such irregularities of surface, mountains, for example, more than 20,000 feet above the level of the sea, depressions greatly below its level, such as is the valley of the Dead Sea in Palestine, which has been found to be more than 1000 feet below the shores of the Mediterranean? And, further, why should there be those differences of structure in the mountain masses, such variety in

the inclination of the strata, and lastly, such diversity in the organic remains which they contain?

The answer to this questioning, as to the former is, expressing it most generally, that the circumstances naturally giving rise to it may be considered as indications and proofs of disturbing causes, variously acting, to which our globe has been subjected, and to which all the phenomena requiring explanation are to be referred.

We speak of the earth as formed of dead, impassive matter, as it truly is; of solid matter, as it also truly is; and we commonly associate with these attributes the idea of its parts being motionless and unalterable, and are disposed to consider it as in a great measure exempt from change and unexposed to influences productive of change, which is far from being true.

The figure of the earth, as determined by geometrical measurement, is that of an oblate spheroid, that is, a globe flattened at its poles and swelling out at the equator; the exact form, it would appear, that a liquid mass of matter must acquire, situated as our planet is in relation to the other heavenly bodies, and revolving as it does.

It would further appear, from carefully instituted trials on the force of attraction, that the mean specific gravity of its mass is five times as great as that of water.

And, further, from various thermometrical ob-

servations made in mines of different depths, that the temperature of the earth increases with the depth from its surface; and at such a rate, that at comparatively no great profundity its substance must be red hot, and the materials constituting it probably in a liquid state from igneous fusion.

These facts, theoretically considered, are important data.

In the internal or subterraneous heat there exists a powerful cause of change. Hot springs, of so common occurrence that few districts are without them; volcanoes, either extinct or at present in operation, of which few countries of any considerable extent are destitute, afford ample confirmation that this cause has widely acted, and is still exerting its influence.

If we examine the products of volcanoes, we find amongst them lavas which have been ejected liquid, and which in cooling slowly have acquired a crystalline structure, not unlike the class of crystalline rocks generally, and of necessity resembling them in being destitute of organic remains.

This resemblance, with other considerations, in which the data just referred to are included, has led to the idea or hypothesis, that all crystalline rocks are of igneous origin; that the materials of them were once in a state of fusion; that their liquid mass has been ejected by some great force

in operation beneath the crust of the earth,—a force such as steam might exert under immense pressure and intense temperature; that in the act of being raised by this force, the incumbent stratified rocks have been ruptured and elevated, raised from their natural horizontal position; and that in slow cooling, the protruded or ejected mass has acquired its characteristic crystalline structure. And phenomena or appearances so generally accord with this idea or hypothesis, that it is now very commonly received by those inquirers who have specially directed their attention to the subject.

When a crystalline rock is exposed unprotected to the atmosphere, it commonly absorbs oxygen, and disintegrates or crumbles into powder, a certain portion of it being decomposed, productive of fine clay, whilst another portion, crystals or grains, which resist change, fall out, having lost their cement as it were, and mingle with the clay.

Water constantly dropping on a rock gradually wears it away, however hard the rock may be; and if the water act chemically on it exercising a solvent power, as well as mechanically exerting one of attrition, the effect is so much the more rapid.

Exposed thus to the action of the atmosphere and of rain, and in high latitudes or at great elevations to the rending power of water in the act of

freezing, rocks disintegrate and decompose. Their loose detritus is washed from the mountains and hills into the valleys and plains, and may from thence be conveyed by streams and rivers into the sea, and there be spread abroad, or even carried to great distances by the force of currents, till it finds a place of rest in the depths of the ocean.

Volcanoes eject, not only liquid lava, but also fine ashes and scoriæ; these falling from the atmosphere, often form islands and districts of country, composed of tufas resembling sandstones, stratified in their structure, either horizontal in their position or inclined, according to circumstances. The finer volcanic ashes may be spread widely by the wind, and subside on the sea, where sinking they may form other strata, and even be mixed with materials derived from the land; or even finally become interposed amongst strata so derived.

In this manner it is inferred, that the various stratified rocks may have been formed, and deposits of clay and sand produced; and the former, whether containing organic remains or destitute of them: the kind of remains, or their total absence, denoting, in a certain manner, the epoch in the earth's history to which their origin belongs. Thus, if destitute of organic remains, pointing to a period of formation anterior to the existence of organic life; if containing such remains, marking

a period more or less ancient, according to the species disclosed; if chiefly of extinct species, denoting a very early period; if entirely of existing species, then, on the contrary, a very recent period.

Besides the causes specified, viz. subterraneous heat acting from beneath the surface or crust of the earth, and atmospheric air and water taking effect above, there are others which may co-operate and produce certain results not insignificant in the history of change of our globe.

The atmosphere, when free from mist and clouds, in its perfectly transparent state, offers but little impediment to the passage of the sun's rays, and they consequently have on it no considerable heating effect; where they strike on the earth's surface, there this effect is chiefly produced, and in degree according to the quality of the surface.

If a mixture of two gases, chlorine and hydrogen, in equal volumes, be exposed to the sun's rays, under an impulse received from them, they unite rapidly, so as even to produce inflammation, and an acid gas, the muriatic, results. Various other changes might be mentioned, some of them of union, others of them of the separation of elements, or of composition and decomposition, from the influence of this agent.

If electrical shocks are passed through a con-

fined portion of atmospheric air, and if, after a large number have been transmitted, the air be examined, traces of an acid will be detected in it, a little nitric acid having been formed, the electrical influence having produced the union of some of the oxygen and azote in the proportions necessary to give rise to this acid.

If a weak metallic solution be exposed to a feeble current of voltaic electricity, and it be long continued, after the lapse of a certain time crystals will be observed to be formed, varying in their kind according to the quality of metallic solution employed, and often closely resembling native crystalline minerals, especially such as occur in metalliferous veins.

If transparent glass be long exposed to a moderate degree of heat, an annealing temperature, greatly below its fusing point, from being excessively brittle and liable to break, as it is when cooled rapidly, it loses that degree of brittleness and tendency to break, and is so rendered fit for ordinary use, still retaining its transparency.

If it be longer exposed to the same temperature, and for a very long time, its structure becomes altered without its composition being changed; it acquires an obscure crystalline texture, ceases to be transparent, and is comparatively broken with difficulty.

These facts I mention, to show that the impon-

derable or ethereal agents, heat, light, and electricity, are not inoperative; and that even when of ordinary intensity, they are capable of producing many and various effects, some of which may be constantly taking place under their influence, in the atmosphere, at the surface of the earth, and beneath its surface. A long continued temperature, of moderate degree, may conduce to give a crystalline arrangement to the particles of certain rocks. Electricity acting in feeble currents in metallic veins, may tend to the production of crystalline minerals and of native metals in those situations. The same power may promote the formation of nitric acid in the atmosphere; and the acid so formed may contribute to the production of nitrous salts in the earth. And, lastly, if I may say lastly, the sun's rays acting on the surfaces of rocks, exposed as well to the air, may promote their decomposition by effecting, with the aid of oxygen and moisture, the production of new combinations such as are favourable to fertility in the resulting soil.

In the preceding lecture on the atmosphere, I brought under your notice the antagonist and compensating or correcting influences of animal and vegetable life in preserving its uniformity of composition. In the earth we witness influences of the like kind, as it were opposed to each other, and producing opposite effects. Water, in its

operation, aided by air, may be considered as destructive, wearing away rocks and mountains, and carrying their comminuted parts to lower levels, and even into the sea, to be buried in its depths. Fire may be considered as restorative; acting below the surface, it melts and also consolidates according to its degree of intensity, tending to reproduce crystalline rocks in one instance, and stratified in the other. Even when it appears most eminently to act according to our ordinary notions of its operation as a devastating and destroying agent, for example, in the eruption of a volcano, the ashes which are discharged into the atmosphere and are widely scattered by the winds, even when they fall on the adjoining countries, may help to supply the place of the old surface-materials carried away by streams and floods, and to renovate the soil with new elements of fertility. And acting in another form and manner, the same power which occasions volcanic eruptions appears to be productive of another effect, viz. the gradual elevation of the bed of the sea, tending to the formation of new land, of which we seem to have examples in the extension of certain coasts, and the appearance of rocks and dry land above the waves, preceded by a gradual diminution of the water over the spots where these remarkable phenomena occur.

Of most of the geological changes alluded to in

the preceding remarks, the West Indies afford well marked instances.

From the continent of America are to be seen vast rivers flowing into the sea, turbid with the detritus of the country through which they have descended in a course of thousands of miles, and discolouring and freshening the waters with which they mix at an extraordinary distance from land. Between their mouths on the coasts and their rapids on the boundary hills of the interior, immense level, or almost level, tracts occur; marsh, morass, and sand bank, neither land nor water, covered chiefly with aquatic plants; tracts formed by deposits from the great rivers, and commonly of materials somewhat coarser and heavier than those which are longer suspended, and are carried out into the sea in consequence of their greater fineness.

In many of the islands, not only are there rocks to be seen evidently of volcanic origin—columnar basalt, trachite, and many varieties of tufa—but also craters from whence eruptions have taken place, and in which the fires are hardly yet extinct that once acted, as is indicated by the hot steams and exhalations still proceeding from them.

Moreover, in some of these islands, rocks of volcanic origin, crystalline in their structure, and totally destitute of organic remains, are associated with others of a perfectly different character, stratified and abounding in organic remains, various

species of sea shells, and of coral; and it is worthy of notice, that in one of the instances in which the appearance is best observed, viz. at Brimstone Hill, in St. Christopher, the volcanic rock is flanked by the stratified rock, and the latter — an aggregate of shells, coral, and calcareous marl, has its strata highly inclined, tilted up as it were by the former.

Other islands or parts of islands occur, in which there are only partial volcanic traces, and these not so much of volcanic action and disturbance on the spot, as of materials, such as ashes, thrown up by volcanoes, and those distant ones. This island, Barbados, is an example. Composed in great part of a calcareous aggregate in which organic remains abound, it has very much the character in its peculiar features of having been raised from the bed of the ocean, (where it is certain it was formed) by some mighty force, slowly acting, and which it is probable is acting still.

Nor is there wanting in these seas instances of islands in which almost every variety of formation is exemplified. Barbados, in its smaller portion, the Scotland district, exhibits some interesting varieties, such as beds of chalk abounding in the remains of microscopic animalcules, strata of sandstone, some siliceous, some calcareous; the one without organic remains, containing, however, de-

posits of coal and bitumen; the other—the latter, having included in them organic remains, and of a kind to connect them with the calcareous rock of which the larger portion of the island is formed, for instance, the spines of echini and the teeth of squali. The larger islands, Trinidad and Jamaica, Port Rico and Cuba, yield examples, I believe, still more in point. In Trinidad, I am not aware that any volcano, or crater of one, has been discovered, or any rocks evidently volcanic in their origin; but, from the imperfectly crystalline rocks, destitute of organic remains and distinct stratification, to clays and marls, to mud eruptions or volcanoes as they are sometimes called, through limestones and sandstones stratified and containing organic remains, a tolerably well marked series, would appear to exist. In the adjoining and smaller island Tobago, some of the same series are observable; but in a broken manner, not a little interesting and instructive. There highly crystalline rocks, destitute of organic remains, are in juxtaposition with others abounding in these remains; coral rock is even found resting on granite; and in another situation the latter rock is contiguous to mica slate, in which quartz in mass is not of rare occurrence.

In considering the composition of the atmosphere, we have seen how admirably it is fitted for the uses to which it is subservient in the

great scheme of Nature's economy; and especially in relation to life, vegetable and animal. What is to be witnessed on the earth is not less demonstrative of the same fitness, and which, if time permitted, might be traced through various details. I shall allude only to a few circumstances in illustration.

Without a soil, and that formed from the disintegration of rocks, either near or remote, vegetables could not exist, nor consequently animals.

Without irregularities of the earth's surface, there would be no springs, no rivers, nor lakes; no water not salt or brackish; no land that we can imagine fit for animal life, except of a very low order, and least of all fit for man.

Instead of the varieties of rocks which we now have, with deposits in beds included in them, of coal, salt, iron ore, and most of the ores affording useful metals in veins; were they, I say, instead of being thus separated, confusedly mingled together, of what advantages would not man be deprived! If he could exist at all, it would be in a most barbarous state, — much in the condition of the rudest tribes of whom we possess any knowledge.

Constituted as soils are at present, they yield to plants all the inorganic elements which are required for their support; and by transfer in food, for the support of animals. Hence the phosphate

of lime is obtained, which performs so important a use in the animal frame; hence, either directly or indirectly, the carbonate of lime which supplies the place of the phosphate in many of the inferior orders of animals; and hence, too, that of silica, which enters into the composition of the frame-work of so many plants.

There are certain metallic substances which are poisonous to animals; and sooner or later, if taken into the system, are destructive of life, or highly injurious; such are, especially, arsenic, lead, and mercury in particular combinations. I am not aware of any natural spring that has yet been discovered, the water of which is contaminated with any one of these poisonous compounds; or that any harm is known to have been produced by them, excepting when taken accidentally, or given intentionally with evil design. It appears to have been wisely ordered, that as they exist in the earth, they should be shut up and hid in deep veins; and commonly so combined as to be insoluble and innocuous.

There are certain other compounds, chiefly saline, which have a beneficial effect if judiciously taken, in correcting deranged states of the system. These which have thus medicinal virtues are often found in a state of solution in springs, and of that degree of strength, and often of temperature, as to be immediately fit for use, — either to be taken

internally, or to be employed externally in the way of bath or douche. This surely is a happy provision of Nature for administering to the relief of ailments to which the body is subject!

I shall mention one instance more of apparent design in the situation in which a saline matter is found chiefly to occur. I allude to nitre — a substance so important in various relations. It is useful as a manure; and it forms spontaneously in certain soils. It is useful in hot climates for the cooling of drinks,— an effect it produces when dissolving in water, in passing from the solid into the liquid state; and it is met with in the greatest abundance, comparatively, in the surface-soils of the hot plains of Bengal. I need hardly advert to its other uses, — as in the preparation of aqua fortis, and of gunpowder — both of them now most important agents in the arts, to say nothing of the latter as the material of war. How wisely it seems arranged that this salt should be found under the circumstances mentioned; and that the extraction of it from the soil should require some art and industry, and the preparation from it of powerful and destructive compounds still more labour and skill!

In the works of creation there is always design and order — if I may be permitted the expression — so varied and great as almost to exceed comprehension: and *this*, combined with such arrange-

ment of the several parts, as to be eminently beautiful, — so as to make an agreeable impression on the senses, so to speak, before affecting with delight the reflecting mind. How remarkable is this on the earth! The mountain that cools the air and condenses the vapour, sending down refreshing streams to the valley and plain, is a sublime object in the landscape. Every hill, every rock, which has a similar beneficial effect, in a minor degree, varies and imparts beauty to the scene. Further, in accordance, seemingly, with this plan of usefulness and beauty combined, it may be remarked, that every well directed effort of man by his labour and skill to improve cultivation and extend fertility, whether by the planting of a fruit or a timber tree, or the reclaiming a spot of barren land, seems not only to add a charm to the country, and an attraction, but to improve also and render more wholesome the air and the climate.

It has been supposed by some individuals that geological studies — the study of the natural history of this our earth — has a tendency to lead to religious doubt and infidelity: the opinion I hope and believe is not well founded. I shall not enter into a laboured defence of these pursuits, believing it to be quite unnecessary, especially after the sentiments I have expressed in the introductory lecture, of the tendency of scientific inquiry to excite not

only a love of truth, but also to produce a humble feeling of mind, from comparing the small extent of our knowledge with the vast extent of our ignorance.

Apart, however, from such general considerations, — apart from the influence on the mind, from observing the wonderful order, harmony, and adaptation displayed in the structure of the earth, even as I have faintly brought it to your notice,— I cannot but think that the study in question affords admirable arguments in favour of natural theology; and is better fitted, perhaps, than any other train of inquiry to check scepticism and infidelity, especially when associated with daring presumption, at the fountain head.

In the preceding Lecture, speaking of the series of forms of organised beings, it was mentioned, that the species, although exhibiting a gradation from the lowest apparently to the highest, do not blend and run confusedly into each other, but are kept distinct — each apart from the other, each as if called into existence by a special act in the exercise of creative power. And, in accordance with this, it may be remarked, is the most trustworthy and extensive experience which we possess, — there being no well authenticated instance of a single species of organic being appearing within historic times — extending beyond two thousand years, which had not previously existed;

every asserted instance of the kind, like all those of the same category, which once excited attention under the designation of equivocal generation, having been found to be fallacious when carefully examined. A great fact this, and a conclusive argument against the materialist and his doctrine of progressive developments; and though not strictly geological, it pertains in a manner to the following, which is so.

In examining the several rocky strata and deposits which occur at the surface of the earth, we have seen how the geologist has found in some of them containing organic remains, the vestiges only of extinct species; in some, a mixture of these and of existing species; and in others, the latter only; and farther, how he has discovered no where amongst these various remains any traces of man. This is a remarkable result; and now after so much research, and that so widely made, and very much directed to this particular point, it seems hardly questionable. Admitting it then, as a fact, what is the conclusion from it? Is it not evidently this, that man, amongst animals, was not an early inhabitant of the earth, that he is a being of comparatively recent production? And, what is the inference from this? Is it not as clearly, that a special power has been exercised to which his being is owing? And, how, it may be humbly asked, can we associate

with such power, any idea but that of Divinity, that is, the idea of all that we hold to be most perfect, most excellent, most powerful, united in one?

Matter, as we define it, is essentially dead and inert; incapable therefore in itself of change. It is an old argument and a fine one, that *motion*, that is, the power to produce it, is a proof of the existence of a something different from matter, viz. *mind;* and duly considered as exhibited in its harmonious manifestations, that of a Divine mind.

The exertion of a creative power includes the idea of a moving power, and when displayed in the production of a complicated organised structure, endowed with life and intelligence, such as that of man, leaving out of the reasoning account the whole of the universe besides, have we not proof, added to proof, and this afforded by the studies under consideration, in support of natural theology?

LECTURE IV.

ON THE OCEAN.

THE ocean is, as you know, that vast collection of fluid matter, which washes the shores of our continents, encircles islands, and in its various ramifications and minor parts forms seas, gulfs, bays, and channels. Vast as it is, under the scrutiny of science it is neither boundless nor immeasurable, though it is designated as both in common poetical language. Compared with the earth's surface which rises above it, it would appear to be of much greater extent, even in the proportion of three to one, and this with a mean depth of not less than three miles. This estimate as to its profundity is derived from refined calculations connected with the theory of the tides, and from carefully made, though not sufficiently extensive observations, to determine their average height. In no other way, perhaps, could the result even as an approximation have been obtained, inasmuch as the bottom of the ocean, like the dry land, is infinitely diversified, having its

valleys, plains, and mountains; and farther, from being in most places unfathomable, that is, too deep for the plomb-line to reach its bottom, its greatest depths being supposed to be little short of nine miles.

As the atmosphere receives into its expanse, portions of all fluids that are elastic, that is, of all airs and gases, as the earth is an aggregate of all that is permanently solid, at ordinary temperatures, so is the ocean to be considered as a compound, a solution of all that is permanently soluble and fluid, or rather of parts of all such belonging to the surface of our globe, and which are not decomposable by the agencies to which they are exposed; and, further, its basin, that is, the depression of the earth which holds it, is to be considered, with a few exceptions, their appropriate receptacle and reservoir. The few exceptions alluded to, are instances of similar depressions, but on a comparatively small scale, performing the same part, such as that which holds the Dead Sea in Palestine, and the Caspian in the western part of Asia, both these seas having no communication with the great ocean, the level of their waters being depressed by evaporation, depending on special causes there acting, below the ocean level.

The main constituents of the immense fluid

mass of the ocean are water and common salt; both of them, as you are aware, compounds; one of hydrogen and oxygen, the other of chlorine and the metal sodium — hydrogen the lightest of the gases; sodium one of the lightest of the metals, lighter than water; hydrogen in combining with oxygen to form water, producing the most intense heat we are capable of exciting artificially; sodium also in combining with chlorine to form common salt, affording an instance of combustion.

Of these two ingredients water and common salt, the water which is the solvent, constitutes by far the larger proportion, amounting to about 97 per cent; common salt, being little more than 2 per cent.

Of the other ingredients, in smaller proportion than common salt, altogether little exceeding 1 per cent., the principal elements, besides chlorine, are magnesium and its oxide magnesia, lime, and sulphuric acid.

The following are the results of an analysis of sea water taken from Carlisle Bay in this island, which I have made with some care: —

183·8	Chlorine	in 10,000 of sea-water.
16·7	Sulphuric Acid	
4·8	Lime	
24·5	Magnesia	
·44	Carbonic Acid	

These numbers represent the proportions of the elements obtained by the analytical processes employed. In the following, they are shown in groups, as it may be imagined they exist in the water:—

246·6	Chloride of Sodium (common salt).
44·8	Do. Magnesium.
15·3	Sulphate of Magnesia.
11·3	Do. Zinc.
1·0	Carbonate of Lime.
1·0	Loss or not accounted for.
9680·0	Water.
10,000·0	

Besides the ingredients named there are many more, which are in still minuter quantity, such as free carbonic acid gas, oxygen and azotic gas, iodine, bromine, and fluorine, and potassa.

The ingredients existing in largest quantities, those first mentioned are easily detected, and their existence demonstrated.

Almost the whole of the water may be separated by distillation. Here is an example of this. You see before you the distilling apparatus. The sea-water was introduced into the retort; the retort was connected with a receiver. As the water boiled in the retort, its steam rose and was condensed, and the saline matter remained.

This, I may remark, illustrates what takes

place in salines, or salt-pans, in which salt is made, as the expression is, on a large scale, from sea-water, by natural evaporation, under the influence of the sun and wind in dry seasons. The identical process, on a minute scale, you may most easily witness by exposing on a plate or saucer a little sea-water to the open air, in ordinary weather, provided it be dry. In a few hours you will find the shallow vessel incrusted with salt, and the water dissipated, having passed into the air as vapour or steam. The one on a large scale, the other on a minute one, affords a good example, I may observe, of the assistance that man derives from the powers of Nature, on so many occasions, in the useful arts, especially the chemical. These powers, indeed, when taken advantage of to the utmost, aid him more effectually than any of the imaginary genii which are called into action in the stories of Arabian romance.

The several elements of the compounds existing in sea-water constituting the saline residue, may be demonstrated, and their proportions determined, by certain tests and analytical methods. These it will be sufficient very briefly to notice and illustrate by experiment.

Chlorine has a great tendency to unite with silver; and, in consequence, this metal is pecu-

liarly fitted to separate it from its combinations. If I add a solution of nitrate of silver to a portion of sea-water, you will perceive that immediately a very copious precipitate will be produced, which is chiefly chloride of silver, a compound insoluble in water.

Barytes has a like powerful tendency to combine with sulphuric acid, forming with it an insoluble sulphate. This compound will be formed when I add a little of a solution of a salt of barytes, such as the nitrate, to another portion of sea-water.

Oxalic acid has a similar tendency to combine with lime, and form an insoluble compound. You will see the effects of a small portion of it added to another portion of sea-water.

Magnesia is not less readily demonstrated when existing in solution. If ammonia — that is, a solution in water of ammoniacal gas — be added to sea-water, it will occasion a precipitate, which precipitate is magnesia; and the test of it is, that it is redissolved on the addition of some muriate of ammonia, magnesia forming with muriate of ammonia a double salt, which is readily soluble; and a further test is, that on the addition of phosphate of soda, a still more copious precipitate will be produced from the formation of another double salt, which is insoluble and crystallised. The ammo-

niaco-magnesian phosphate. Of the ingredients which exist in sea-water in very minute quantities, the presence of carbonate of lime, carbonic acid, oxygen, and azote, may be demonstrated without much difficulty.

Carbonate of lime is, by itself, insoluble in water; but when carbonic acid is contained in water, then it is soluble; and, consequently, when this acid is expelled, the carbonate of lime is precipitated. If sea-water be exposed to the sun in a bottle, it becomes heated, a good deal of the carbonic acid is liberated, and in a day or two, on careful examination, a minute deposition will be visible on the inside of the glass, consisting of carbonate of lime, in a crystalline state in part, and in part not; and where not, I believe in consequence of a little vegetable matter having been deposited at the same time. The whole of the carbonate of lime in any quantity of sea-water may be obtained by evaporating to dryness and redissolving the residue in water purged of air; the carbonate of lime, being insoluble, will remain when the saline matter is dissolved, with the exception, indeed, of a portion of sulphate of lime; to separate them—the carbonate and sulphate — an acid must be employed.

The oxygen and azote which exist in sea-water may be expelled by boiling the water in a flask or retort, connected with a pneumatic apparatus.

This is remarkable in the air thus expelled; the proportion of oxygen in it is larger than that which exists in the atmosphere, mixed with azote. Instead of being about 20 per cent., it has often been found so high as 31, and even 39 per cent. Though very worthy of note — in which sense I use the term *remarkable* — the circumstance is not surprising, inasmuch as oxygen is taken up in larger quantity by water than azote is: in like manner, compared with the azote, it is found in larger proportion than in the atmosphere, in dew, in rain and in river water.

The presence of the other ingredients named as existing in sea-water in minute quantities — even more minute than the last mentioned — such as potash, fluorine, iodine, and bromine, cannot be demonstrated without much difficulty.

The latter three are simple substances, in some of their properties analogous to chlorine and oxygen, and, in consequence, they are often classed together, analogy of properties being the principle of classification.

In a former Lecture I have made mention of fluorine, at present one of the most mysterious substances in chemistry. It has recently been detected in sea-water in combination with lime; a compound in its mineral state known by the name of fluor-spar, which is slightly soluble in water.

Of the other two remarkable substances here are specimens before you.

Iodine is, you perceive, in its appearance not unlike plumbago. It is nearly five times as heavy as water; it fuses at 225° Fahr., *i. e.* about 13° above the boiling point of water; and boils at 347°. Its steam, as I shall show you, is of a beautiful violet colour; whence the name of the substance, viz. from the Greek word *ἰώδης*, signifying this colour. It has another characteristic property; iodine combines with starch, and imparts to it a fine blue colour, and is thus a valuable test of it. This is easily shown by mixing together some starch in a gelatinous state and a solution of iodine in alcohol and water. As iodine exists in sea-water, it is in combination with an alkaline metal.

Bromine, the other substance, is, you perceive, a reddish-brown liquid. It is not easily frozen; is very volatile, boiling at 116°, producing a deep red steam or gas, of a very offensive and oppressive odour, whence the name given to the liquid, also from a Greek word (*βρῶμος*), signifying this quality.

Further research, carefully conducted, will probably bring to light other substances existing in sea-water; and, it may be, some substances not before known, such as were those last mentioned, till they were detected in this fluid or in

its products. And that very many compounds already known as existing in the earth may be detected in the waters of the ocean seems highly probable, taking into account, as already remarked, that it is the common receptacle and reservoir of all soluble matters passing into it, capable of resisting undecomposed the agencies to which, when there, they are subjected.

With your permission I shall offer a few remarks in relation to this limitary circumstance.

The decomposing agencies alluded to are, in their fullest extent, necessarily vague and not easily defined, as they may exist, not only in the ocean-water, but also in the solid matters constituting the varied bed of the ocean. Some of them, however, are sufficiently distinct. I shall adduce a few instances.

As chlorine in combination is so abundant in sea-water, it is manifest that no salt of silver can be contained in it.

As sulphuric acid is present in it, it is equally manifest that neither barium nor lead can be retained in solution in it.

As sulphuretted hydrogen is frequently formed in the sea, especially along coasts where vegetable matter is abundant and the sun acts powerfully, and as it has the property of precipitating most of the metals from their state of solution, converting them into insoluble sulphurets, there

seems in the circumstance sufficient reason for infering that such metals cannot exist in solution in sea-water. Admitting this view to be correct, sulphuretted hydrogen, instead of being a cause of malaria — the generator of the direful fevers that prevail periodically on the western coast of Africa — might rather be held to be designed by Nature for the salutary purpose of preventing the ingress of the metallic mineral poisons into the sea.

All the soluble compounds of iron and copper are decomposed by lime, and also by carbonate of lime, which, as already observed, is found in sea-water, and is so abundant in many rocks washed by the sea, and in so many animal and vegetable textures belonging to the sea. This will account for neither of these metals existing in sea-water; and also, in part, for the remarkable manner in which the former metal, iron, is diffused, it being rare to meet with a single rock or portion of soil destitute of it. In its widely diffused state, in its oxides, it may be considered as the great colouring matter of inanimate nature, it being without a rival, if carbonaceous matter be not an exception, which, in point of frequency of occurrence, is hardly second to the ferruginous.

In the same way may be explained the absence of aluminous salts in the ocean, all these in

like manner being decomposed by lime or its carbonate.

These instances may suffice as examples of the limitary agencies referred to. On the other hand, if we consider the compounds which are likely to exist in the ocean, not liable to be decomposed by the agencies such as those referred to, or any known to be in operation, we might mention certain nitrates, as those of lime and the fixed alkalies, and of the volatile alkali; and of the latter, also, in combination with muriatic acid; and phosphate of lime dissolved by means of carbonic acid.

If these compounds are contained in sea-water, as I venture to anticipate, being, as we may be sure they are, in excessively minute quantities, they will be detected with difficulty, and only as the result of experiments made expressly for the purpose of bringing them to light. I may add, that when I have tested for ammonia common salt not carefully refined, extracted from sea-water, or the mixed salts obtained by its evaporation, I have not failed to observe slight traces of it, and this by means of a very simple method, the merely mixing it with quicklime and bringing near the mixture an acid which had just ceased to emit visible fumes; a renewal of its fumes (as happened) was proof that ammonia was disengaged, separated by the lime from the common

salt. And I may further add, that when seeking specially for phosphate of lime, I have also detected traces of it in sea-water. It is shown in a satisfactory manner by precipitating first by ammonia after the addition of some muriate of ammonia; collecting the precipitate on a filter, redissolving it in muriatic acid, and again precipitating by ammonia. A repetition is necessary, in consequence of a portion of carbonate of lime having been thrown down in the first instance, from the neutralisation of its solvent, the carbonic acid, by the volatile alkali. In one instance that I attempted to determine the proportion of phosphate of lime, it appeared to be less than the one hundredth part of a grain in ten thousand grains of sea-water.

From the consideration of the chemical composition of sea-water, let us now proceed to give attention to some of its properties, which are not less remarkable than those belonging to the atmosphere or to the earth, and are equally demonstrative of wonderful and harmonious design, especially in connection with organisation and life; and that not only in the instances of species of animals and plants, the habitations of which are the ocean and its shores, but extending also to others, and eminently to man.

1st. *Of its Density.* — Although so immense the extent of the ocean, stretching from pole to

pole in every variety of climate, yet the density or specific gravity of its water varies inconsiderably where no manifest disturbing cause interferes, such as the proximity of great rivers, or of vast fields of ice. It is commonly found to be between 1026 and 1028 to pure water as 1000, which is about the same as the specific gravity of the fluid part—the serum of the blood; a coincidence, I believe, not without import. In the instances in which a greater difference has been found, or has been stated to have been found, it is questionable whether it has not depended on some inaccuracy, either in the manner in which the specimen of water weighed was taken up, kept, or tried, or on some casual circumstance, such as a preceding calm of unusual duration, or a heavy fall of rain.

As the specific gravity or density of sea-water depends on the quantity of its saline contents, so the little variation of this quality is a proof that these, its saline ingredients, are equally constant in quantity; and it may be inferred that this constancy has prevailed in the waters of the ocean for a very long period, and is likely to continue so to prevail. The saltness of the Mediterranean Sea little exceeds, if at all, that of the Atlantic at the present period. And as the level of its shores now are much the same as they were generally, as well as can be ascertained, more than 2000 years ago, and as the same fishes inhabit its

waters now as when Aristotle wrote and described them, may it not fairly be inferred that in this lapse of time no sensible change has taken place in its density, and if not in it, *à fortiori* not in the ocean, the latter being exempt from certain causes, I will not say existing, but which have been supposed to exist, affecting the former, and to have a tendency to increase its saltness; or, in other words, its density.

2dly. *Of its Temperature and of its Freezing Point.* — As regards the temperature of the ocean, there is this marked difference between it and the atmosphere, owing to the different qualities of the fluids of which they are formed. The atmosphere, we have seen, owes its temperature chiefly to heat reflected from the earth. The ocean owes its temperature principally to heat which it has absorbed, derived from the sun's rays, which in passing into it, the medium not being perfectly transparent, are gradually extinguished before they can penetrate to any great depth. Consequently, in all warm climates, the temperature of the ocean is highest at its surface, and that when under the influence of the mid-day sun. Immediately after noon it begins commonly to fall, and continues slowly, very slowly, falling till sunrise, when it changes, and till noon continues as gradually to increase. The *maximum* temperature of the ocean, even within the tropics, rarely

exceeds 81° or 82°, and its variation in the twenty-four hours seldom exceeds 4°. Beneath the surface, in warm climates, its temperature would appear uniformly to fall, diminishing with the depth. At the greatest depth to which a thermometer has been sunk, about 1000 fathoms, in one instance there was a fall of 38°; in another, of 31°. In temperate climates it is probable that the same law prevails, *i. e.* of a limited decrease of the temperature with the depth. But in the high latitudes towards the poles, from the observations which have been made, it would appear that the temperature, also limited, increases with the depth,*

Fresh water possesses the singular and important property of being of greatest density or specific gravity about 40°, becoming lighter as it falls towards the freezing point, and, consequently, insuring in all considerable collections of water, in all deep lakes, comparatively warm water below, even should their surface be covered with ice, and so effectually preventing the conversion of the whole of their mass into ice.

* From recent observations there is reason to infer that the temperature of the deep ocean throughout is about 40°, the depth at which it is at this temperature varying with the latitude; at the equator, being at the depth of about 7200 feet; in latitude 56° at the surface; and in latitude 70° at the depth of about 4500 feet.

Sea-water, it would appear from the most accurate experiments that have been made to determine the point, does not exhibit the same peculiarity. Its density seems to increase within two or three degrees of its freezing, when it diminishes a little from expansion. But, then, sea-water, it is to be remembered, differs in another, an important respect, from fresh. As a higher temperature is required to make it boil, so a lower temperature is necessary to freeze it. When kept still, as it is likely to be at any considerable depth, it has been observed to be fluid at 19° Fahr., or 13° below the freezing point of fresh water, a circumstance which may have a material influence in the polar seas.

3dly. *Of the solubility of its saline contents.* — As regards the quality of solubility, common salt — the principal and most important ingredient of sea-water — has this remarkable property, that heat does not sensibly increase it, nor cold diminish it; and, consequently, the solvent power of the water of the tropical ocean, in relation to it — common salt — is the same as that of the polar; is, in brief, uniform throughout, in accordance with, and conducing to, a nearly uniform density.

4thly. *Of its currents.* — As in the atmosphere winds, aerial currents, agitate and tend to mingle intimately its different parts, so in the ocean water-currents, variously produced, have a like

commingling effect; and to this probably the little variety of density and composition of its waters, as a whole, may in part be attributed. It would require to inspect a chart of the ocean-streams to have any tolerably just idea of their number and magnitude, even of the surface-streams, exclusive of those which exist in deep water, and which, probably are not less important in their influence. The principal circumstances which seem to have effect in producing currents are, besides the attraction of the sun and moon in giving rise to the tides, the influx of large quantities of fresh water; difference of density, depending on the temperature of the water; and strong prevailing winds, blowing steadily in the same direction.

The great rivers of America seem to diminish the density of the ocean, and this at the distance of many hundred miles from their outlets; a change necessarily indicative of a current. It is not uncommon for the sea between Tobago and Trinidad, more than 300 miles distant, to be discoloured when the Oronoco, and the other large rivers adjoining it, are in flood. In July last, when the sea was in the turbid state mentioned, a portion of water I had taken up where there was a strong current, was, I found, of the low specific gravity 1014; and on rest, after a little while, a minute sediment of fine earthy matter was seen collected at the bottom.

Connected with difference of temperature, there is reason to believe, that currents of cold water are constantly flowing from the polar towards the temperate, and from them into the tropical seas; and, in connection with prevailing winds, that some of the most important surface-currents are flowing in a contrary direction, viz. from the tropics towards the arctic and antarctic circles; and further, that all of them, however occasioned, including the great tidal waves, are co-operating to effect that intimate mixture of the waters of the ocean, so remarkable, already pointed out.

We have thus seen the ocean, as it were, in its passive state; let us now consider it in relation to the economy of Nature, in which it performs so many and those so important parts. Its two principal ingredients, you are aware, are water and common salt; the one essential to vegetable as well as to animal life; the other hardly less necessary to the health of animals, as without it, it would appear, most of the larger animals with the habits of which we are acquainted, sooner or later fall off in condition, and become diseased; and they all, whether domestic or wild, seem to have a decided liking for it, as it were, an instinctive taste, imparted, no doubt, for a beneficial purpose.

Now, the ocean is equally the great and inexhaustible reservoir of water and of salt. The

one is constantly rising from its surface in the state of an invisible gas or vapour, under the influence of the sun and winds, to be diffused through the atmosphere, and over the earth, there to form clouds and mists, hail, snow, and rain, according to circumstances of change of temperature, and thence to fall, according to the climate and season of the year, either — as in northern regions in winter—to protect the ground, by a bad-conducting covering of snow, from the effects of intense cold; or in spring and summer in these regions, and in warm climates at all seasons, to nourish vegetation, feed springs, and replenish lakes and rivers, which in their course and termination, passing into the ocean, replenish it. So perfect is this order of events, that it has become a symbol of sublimer and more mysterious changes, adduced to aid imagination when exercised on some of its highest aspirations.

The common salt, the chloride of sodium, which the ocean contains, is easily procured for use, being separable from most of the other saline parts, in consequence of its different degree of solubility; chloride of magnesium being far more soluble and deliquescent in ordinary states of the atmosphere; sulphate of magnesia also being more soluble, especially at an elevated temperature; and sulphate of lime being far less soluble. So easily is common salt separated by

spontaneous evaporation, that it may even be collected from the rocks on the sea shore, in dry weather; and is often so collected, especially by savage tribes.

When we consider how great a necessary it is as a condiment, and, in consequence, the millions of pounds of it which are extracted annually for the use of man, we cannot but perceive that the supplying thus of this want is not without use in relation to the ocean itself, tending to prevent an undue accumulation of salt in it, and its conversion finally into a *dead sea*, like that in Palestine in which the proportion of saline matter is nearly one half the weight of the aqueous parts, and in which, in consequence, no aquatic plant or animal can exist. The river Jordan, which passes into this sea, or rather lake, contains no more saline matter than ordinary rivers, all river-water containing a minute portion. It is not, then, from having more salt brought into it, that the waters of the Dead Sea are so intensely salt, but in consequence of its having no communication with the ocean; and this, it may be inferred, in consequence of the evaporation from its surface being unusually great, keeping down the level of its waters. It may be, too, that at some former period, when the valley was formed, strata containing a bed of rock salt might have been broken up, and by its solution

have formed at once a dead sea. Had the specific gravity of its waters been ascertained 2000 years ago, we might, by a comparison of its density now with what it was then, have been enabled to arrive, perhaps, at some satisfactory conclusion on this interesting point. Be that as it may, we know for certain that every lake, without an outlet, must in course of time become a salt lake, and finally, of the character of the Dead Sea, unless the saline matter brought to it constantly is not somehow removed. It might be supposed that a lake so situated would finally be dried up; many in Africa are so — being plains of salt in the dry season, and salt lakes only in the rainy season. Where there is a considerable depth of water, however, and a perennial supply of water by a river, a point of condensation may be produced, such as to establish an equilibrium between the loss by evaporation and the supply by rains and feeding-streams; and probably such a balance is now, and has long been, in operation in the instance of the Dead Sea.* We must remember that, not only is the boiling point higher in proportion to the density or saltness of the water, but also, that in the same proportion, the loss by evaporation from

* That it has long been in operation may be inferred from the description of the Dead Sea by Josephus, from which it appears that the character of this lake was much the same when he wrote as at the present time.

it is slower and less, and that at a certain point of concentration, evaporation may cease altogether.

The other saline contents of sea-water, are perhaps little inferior in use to the principal ingredient, common salt. As regards the human race, the mixed salts, such as exist in solution, are a valuable medicine, and seem as if so intended by Nature. And, from the chloride of magnesium, which next to chloride of sodium is in largest proportion, a useful medicine is obtained, viz. magnesia, the greater part of that employed being procured from this source. Moreover, these salts are not inoperative as manures. Sea-water, when judiciously applied, appears to be highly serviceable in this respect, especially to pasture lands. The chlorides may be of service, particularly when there is no deficiency of lime in the soil; and the little carbonate of lime, sulphate of lime, and salts of the vegetable and volatile alkali present, may also have a beneficial effect.

Another important part performed by the ocean in the economy of Nature, hardly, if at all, inferior to the preceding, is that connected with the distribution of heat, and its equalisation, so far as that is effected.

The ocean is equally the great receptacle and reservoir of heat, and of water, and salt. Within the tropics, by absorbing the sun's rays, it moderates the heat and prevents these regions

from becoming the torrid, uninhabitable ones, which they were imagined to be by the ancients. In temperate climates, it has the same effect in summer, tending to keep the atmosphere cool; whilst in winter it has the contrary tendency, to preserve the atmosphere warm. The same tendencies and effects are witnessed even in the Polar seas; as indeed they necessarily must be wherever there are any great masses of water, keeping in mind as a principle, that water never cools, that ice never forms, without an imparting of heat to the atmosphere; and that water never becomes warmer, nor ice ever melts, without the absorption of what otherwise might be atmospheric heat. Moreover, the peculiarity already alluded to, of salt water increasing in density to within a degree or two of its freezing point, and its freezing point being so much lower than that of fresh water, must have the effect of keeping the Polar seas longer open; and, probably, in some situations, where powerfully influenced by currents and tides, to keep them constantly unfrozen, even throughout the severest winter seasons. Had sea-water the same quality as fresh water as to density connected with temperature, then, as the mean temperature of the Arctic Ocean appears to be below 40°, there is good reason to infer that it would be perpetually covered with ice, and with ice constantly in-

creasing in thickness, rendering those regions quite inaccessible or totally unfit for the resort of the vast number of aquatic animals that migrate to them during their short summer — a long protracted day, the sun, you know, at that season, never sinking below the horizon there. So great is the influence of the ocean in its tendency to equalise temperature, that were not its effects well known from experience, we could scarcely credit them *à priori*. How remarkably is it exemplified in countries bordering on the ocean, or on deep seas, compared with those which are inland, or bordering on shallow waters. The Black Sea affords striking instances of each kind. Its southern shore, extending from Trebizond nearly to the entrance of the Bosphorus, is bold and elevated, and, as is commonly the case, is skirted by deep water. There, a mild winter is experienced; the platanus, the myrtle, the arbutus, are to be seen there; and the two latter growing wild amongst the rocks — proof of the mildness alluded to. On the northern and western coasts of the same sea, which is little more than 300 miles in width, a totally different scene presents itself, and a totally different climate, — a climate which, I believe, was not for its winter severity exaggerated by the Roman poet in his "Tristia." Its shores are low, the adjoining sea shallow, the country inland, a vast naked plain, the prevailing

winds northerly; the great rivers which there empty themselves and freshen the sea-water, flow from the same quarter;—circumstances which together combined, seem to give to its winter climate its remarkable intensity of cold, resembling that almost of a Polar region, denoted by the freezing of the great rivers interrupting their navigation, and the freezing of the shallow brackish water many miles from land.

Did time permit, and were it advisable, numerous other examples might be given of the kind; contrasts showing how the sea renders the climate of certain districts of coast mild and supportable, which from their latitudes, were they inland, would be hardly bearable from the rigour of cold; and how other districts remote from the sea, especially if elevated, as they commonly are, are as oppressively hot in summer as they are intensely cold in winter. Ancient Armenia, a great part of modern Persia, Cabool, Affganistan, indeed the whole of the country of Upper Asia, is so characterised. In Cabool, where the winters are so severe that the warmest furs and sheepskins are ordinary articles of clothing, in summer the heats are so great, that the natives, to escape as much as they can from the distressing effects of them, commonly dwell at that season in underground houses.

The ocean, you are well aware, is teeming with

living things, animal and vegetable; it is probably as prolific of them as the earth; indeed, by some naturalists it has been supposed to be more so. Almost every type of existence is there to be met with, from species of Mammalia that suckle their young and breathe by means of lungs, to the several orders of Reptilia, Fishes, Crustacea, and Mollusca, and still lower in the scale of organisation, to the great and miscellaneous class of Radiata or Zoophytes, itself numerously divided, and exhibiting in one of its lowest orders animals which have been called apathic, such as the sea blubber, in which functions are made manifest associated with a very indistinct organisation. The vegetable kingdom within the domains of the ocean is hardly less abundant, though there is reason to believe, greatly more limited in its forms than the animal.

The adaptation of the ocean to its inmates, and of these to the ocean, is equally remarkable and demonstrative of extraordinary design, a skill and contrivance that, when scrutinised even imperfectly, excites our highest admiration. The whale, which in its internal organisation differs but little from the hippopotamus or from the elephant, breathing, like them, atmospheric air by means of lungs, is, you know, in its mode of locomotion and its habits, little different from a fish, swimming by means of extremities in the

shape of fins, and capable of remaining under water a very long time, and this in consequence of a special apparatus for the purpose, not a reservoir of elastic air, but what would appear to be equivalent, without its disadvantages — a reservoir of aerated blood, contained in large convoluted arteries placed between its ribs. The apathic animals (so called from having no visible nerves), such as the medusæ, which constitute, as it were, the other extremity of the scale of aquatic living things, in whom I have remarked that the functions — the indications of life — are distinct, whilst their organisation is most obscure, animals beautiful in their colours, possessing the property of emitting light, on which the luminosity of the sea at night chiefly depends, and having the power of exciting an irritation on the hands of those who touch them like that from the sting of the nettle, — these singular beings consist in great measure of water; it is water that constitutes their bulk principally, contained in a delicate transparent gelatinous tissue, which soon dissolves in the open air, and also, I believe, in fresh water. The density of these extraordinary animals appears to be much the same as that of the sea, or very little inferior to it, and, in consequence, they are sustained in it without difficulty. Farther, the saline matter producing this density is, it would appear, favourable to such

delicate fleeting forms; it may tend to keep them without material change affecting their living condition, much in the same manner as sea-water and the serum of the blood, which, as I have already observed, are nearly of the same specific gravity, preserve unaltered in form the corpuscles of the blood, which may be considered as organised primordia. In the other orders of living beings inhabiting the ocean there are peculiarities of structure, according to the kind of animal, fitting it exactly for its position, not less remarkable than those, to which in the two extremes I have just alluded. It would occupy too much time and be out of place now to enter into details.

All these living beings exist in their watery element by means of the air contained in the water, excepting indeed those of the highest class, that of the mammalia. The oxygen part of this air we have seen is in large proportion. It is as essential to their existence as is the oxygen in the atmosphere to the animals that respire it. Were they deprived of the oxygenous part, they, the former, would perish as certainly as those, the latter, under a similar privation. And as the one class exhales carbonic acid equivalent to the oxygen consumed, so it may be inferred does the other.

Moreover, sea plants under water, exposed to

the sun's rays, have, it has been ascertained, the same power of decomposing carbonic acid gas which land plants possess, retaining the carbonaceous portion to administer to their growth, and liberating the oxygenous portion for the use of animals, thus forming the same harmonious circle. It is a question even whether the ocean, through the instrumentality of the living beings which it contains, has not a decided influence in purifying the atmosphere; or, in other words, supplying to the atmosphere more oxygen than it receives from it. The idea that it may do so seems to be formed by those inquirers who entertain it, in consequence of having found so large a proportion of oxygen in sea-water, as already mentioned, and of some observations seeming to indicate that even infusorial animals in water under the influence of light decompose carbonic acid and evolve oxygen in the same manner as the green leaves of plants. In mentioning this I use terms expressive of doubt, because the observations, till confirmed by further research, can hardly be received as certain.

The carbonic acid which exists, as we have seen, in sea-water, and the small proportion of lime which likewise exists in it *, dissolved by

* From experiments made since the above was written, on a homeward voyage from the West Indies, I am led to infer that carbonate of lime exists chiefly in sea-water, where

means of this acid, though apparently insignificant, are not so in reality; happily illustrating how in the economy of Nature feeble agents, little attracting notice, are employed in the production of mighty effects.

Carbonate of lime is the principal ingredient not only of the hard cases of the numerous order of crustacea, including crabs, lobsters, &c., not only of the shells of the still more extensive order of mollusca, or shell-fish, but also of the stone-like receptacles of the several different species of polyps, so well known under the common name of coral; animals of simple forms, minute size, immoveable, helpless, and individually powerless, and yet, acting conjointly, millions co-operating, rearing up structures of vast magnitude, forming shores and reefs, the foundations of islands, and often islands themselves, one generation establishing itself on the dwellings become the tombs of that which preceded it, these, the stony dwelling places, or the receptacles of the minute animals, being as durable as the creatures themselves are perishable.

Farther, carbonate of lime is not only concerned in the manner mentioned, but also in the produc-

it is most required and where its waste is most easily supplied, viz. near shore: I sought for it in vain in the unfathomable water of the Atlantic Ocean, when some hundreds of miles from any land.

tion of rocky formations. It is probable that many such occur in the depths of the ocean, especially when acted on by volcanic heat. This we are sure of, that they take place on its coasts, and often to a great extent, sometimes almost rivalling in magnitude the coral formations themselves. Round the coast of this island (Barbados) there are many examples of the kind, compact sandstone, consisting of sea-sand, whatever it may be, whether entirely of comminuted shell and coral, or partly siliceous, cemented by carbonate of lime. It is worthy of remark, that such sandstone is most commonly found to occur where a barrier for the protection of the land is most required, viz. where the waves break with greatest violence. And a reason may be assigned for this: the carbonate of lime is held in solution by means of the acid gas already mentioned; it acts only when precipitated; the agitation of the water promotes the escape of the gas and the precipitation of the lime required, and the heat of the sandy shore aids in the effect.

The operations of Nature are often suggestive, affording hints for imitation in the useful arts. It is probable that this mode of the formation of sandstone might be adopted economically for the making of stone for the purposes of building. Were sand introduced into a mould of any form required, whether for a column or a square block,

and water poured on it containing carbonate of lime dissolved by carbonic acid, it can hardly be doubted that the carbonate, as deposited on the escape of the gas, would act as a cement and convert the loose sand into compact, firmly-united stone.

Where the new formation of rock just before described is not in progress, where the sea-sand remains loose, even there, it is worthy of remark, it is not without use. When formed of comminuted shells, as such sand commonly is, it constitutes an admirable material for the improvement of many soils, especially stiff clay soils deficient in lime. This sand is produced, as you are aware, chiefly by the violent action of the waves, exercising apparently a destructive power, and yet, even in thus acting, the consequences we see are beneficial. And were we to consider them more minutely, that is, the good resulting from sand so formed and from the girding beaches consisting of it, we should find the effects to be various, and not a little important, and more than compensating for the wrecking violence occasionally witnessed in the storm and hurricane when the waves are in largest volume, in most rapid motion, and exercising in consequence their greatest power.

At first view it might be imagined, reflecting on the vast expenditure of carbonate of lime constantly taking place in the living and

dead operations thus brought to your notice, that ere long the supply even in the ocean must be exhausted. But there is a provision against this, as simple as it is efficacious. The waters that have exhaled from the ocean, in returning to it, whether directly from the atmosphere in rain, or indirectly in rivers, always bring a supply of carbonic acid; not a drop of rain is destitute of it; not, under ordinary circumstances, the smallest portion of river water; and the living beings in the waters of the ocean exhale carbonic acid, equivalent, it may be inferred, to the oxygen they absorb in performing the function analogous to respiration. The carbonic acid contained in the sea-water derived from these sources, acts on the limestone rocks, where the water is deeper than on the shallow shores, and cooler and less disturbed, and removes a portion of them by solution; and thus helps to supply the expenditure of this material. The steep cliffs of Barbados, where washed by comparatively deep water, as they are in many places, afford as good and as striking examples of this wearing destructive influence by the removal of carbonate of lime by means of carbonic acid, as some of the shallow portions of your shores do of a contrary, a formative influence, from a deposition of carbonate of lime connected with the escape of the same acid gas.

Amongst the constituents of sea-water, iodine and bromine have been mentioned as existing in very minute quantities, in combination with alkaline metals (bromine, it is inferred, chiefly in combination with magnesium) so minute as to be detected with difficulty. Yet even these perform a part, it may be concluded, not unimportant. With phosphate of lime, and probably a very minute portion of ammonia, they appear to be separated by sea plants in the act of vegetation, and, entering into their composition, promote their growth. It is in these plants, consequently, that they become stored up, especially iodine; and thus stored up, it is easily obtained.

Before you is a specimen of the compound in which iodine is found in the ashes of certain of these plants. If this white saline body be mixed with a little black oxide of manganese, adding a portion of sulphuric acid, and applying heat, a decomposition will be effected, a sulphate of potash will be formed, consisting of potassium, oxygen, and sulphuric acid, and the iodine previously united to the alkaline metal [the potassium] will be liberated.

The uses of these substances do not, any more than the uses of common salt, terminate in the part they perform in the ocean; they have ulterior uses; iodine we know has, and bromine probably has. The former in admixture with common salt

in excessively minute proportion appears to have a salutary effect on the constitution, particularly in the prevention of scrofulous ailments; and when extracted, either pure or in certain combinations, it proves a powerful medicine, serviceable in many serious forms of disease.

In this their manifold capacity — first subservient to vegetable growth; next, when thus collected in plants, in store for application to other uses, we have another example of that beneficence which we witness in every department of Nature — in the atmosphere, in the earth, and not less conspicuously in the ocean; good within good, sequences of benefits. How admirable it is that the same fluid mass, readily yielding and yet supporting, should insulate countries, and, at the same time, facilitate the communication of country and country; should afford protection, and yet render commerce easy; should equally mitigate the extremes of heat and cold; and from its several elements should supply the earth with fresh water, its inhabitants with a condiment almost as indispensable, and with valuable medicines; its shores with rocky barriers where most required against the encroachment of the waves; these waves, by their comminuting action, a useful manure in the sand which they produce and throw up; a large class of aquatic animals with strong and secure dwellings; and

these, and all the other numerous races of living things, its inmates, with vital air, the consumption of which by them furnishes food for its plants; and they, the plants, in their turn, restoring the vital air, not only to the ocean, but even it may be to the atmosphere, to preserve a wholesome balance. How admirable, indeed, is all this! To the reflecting mind it constitutes, I cannot but think, the most remarkable of the wonders of the "great deep," and demonstrative of design of a marvellous kind; or, in other words, only of such as we can imagine to be Divine.

In the introductory lecture, amongst the uses of Chemistry recommending the study of the science, I have alluded to its connection with the economy of Nature. In the subsequent ones on the Atmosphere and the Earth, and in this on the Ocean, I have entered into some particulars — briefer, indeed, than I could wish — in illustration. If in the smallest degree successful in the attempt, you must be convinced of the importance of the study, if considered only as a branch of liberal education, as a means of obtaining the most interesting information concerning our globe, and as a source, let me add, of high and of pure intellectual enjoyment. A great living poet *

* See Preface to the 2d edition of the Lyrical Ballads, by Wm. Wordsworth.

has happily pointed out the line of demarcation between Poetry and Science, and the relation of one to the other; how when scientific truths are rendered familiar, they belong to the domain of poetical thought and feeling, and become fit materials for metrical composition. No science, I believe, is better adapted than Chemistry to bring about this familiarity, and in so doing to heighten our taste of the beauties of the outward world, viewing them, as with such acquired knowledge we necessarily must, not merely as objects of agreeable sensations, but intelligently, as parts of a system in which the charm of beauty is always combined with that of usefulness; as parts of a system in which there is order in the midst of the most apparent disorder, and design manifested where, without such knowledge, it never could be perceived or even suspected.

FIVE DISCOURSES

DELIVERED BEFORE THE

GENERAL AGRICULTURAL SOCIETY OF BARBADOS,

AT THEIR

SUCCESSIVE HALF-YEARLY MEETINGS,

DURING THE

YEARS 1846–47–48.

DEDICATION.

TO

THE PRESIDENT AND MEMBERS
OF THE GENERAL AGRICULTURAL SOCIETY OF
BARBADOS, AND OF THE SEVERAL
DISTRICT AGRICULTURAL SOCIETIES OF
THE SAME ISLAND.

Gentlemen,

As the following discourses relate specially to the important pursuits in which you are engaged, and as they were delivered at the successive half-yearly meetings of the General Agricultural Society, of which most of you are members, there appears to me to be a propriety in dedicating them to you.

Other motives, besides, influence me in inscribing them to you—motives of grateful feeling and respect towards you, individually and collectively—grateful feeling for the many kind attentions I

experienced from your members during the three years and a half I was amongst you — a feeling of respect for what I witnessed in the proceedings at your meetings, in the intelligence, enterprise, and anxious desire to improve tropical agriculture there exhibited; and, moreover, for the liberal and generous sentiments expressed on all suitable occasions in the discussions which took place, whether at the sedate time of business before dinner, or after the good cheer of that meal and the cheering glass — "cheering, not inebriating"— that followed it.

I shall long remember the last time I had the honour and pleasure of being present at one of your monthly meetings, viz. that of the St. Thomas District Agricultural Society, which took place in October, at Lion Castle, the elevated and pleasantly cool residence of the worthy president of the Society, John Ellis, Esq. I shall not trust myself to advert to the kind compliments that were paid to me on the occasion, on my taking leave, and in responding to which I could not do justice to my feelings at the instant; but I may indulge myself with here noticing, and in aiding to bring to public notice, the testimony you then offered of respect, regard, and

of gratitude to your late governor, Lieut.-Col. Reid. Never did I witness a health proposed more warmly, or drunk more cordially, or more disinterested encomiums and higher praise bestowed. I regretted there was not a reporter present to make a record of what was said, expressive of the feeling entertained towards a retired governor, who, from a high sense of duty, had tendered his resignation when all ordinary motives, especially of interest, would have prompted a continuance in office. The manner in which, not only one member after another, but several at a time, rose to give utterance to what all felt, was characteristic of the enthusiasm that prevailed, — the result of individual exertion in a high situation, intent on doing good and with effect, and in the least ostentatious way possible. The generous manner in which the Society appreciated such peculiar merit impressed me at the moment, by a kind of reflex action, as most creditable to its members; and may I be permitted to say, high as they stood before in my estimation, raised them in it still higher, and gave confidence that where so much of worth existed, so unexceptionably denoted in the admiration of worth, despair should

be the last feeling to be entertained regarding the destinies of your island, all history tending to prove to demonstration that no country as a body politic, whether small or great, has declined and fallen where there has been the support afforded that private virtue and public insures—the latter the aggregate of the former. That Barbados may be another example of the kind, and especially instructive and encouraging to the neighbouring colonies, is alike my ardent wish, and sanguine hope.

With much respect and esteem,

I remain, Gentlemen,

Your obedient, humble servant,

JOHN DAVY.

Lesketh How, near Ambleside,
January 31. 1849.

INTRODUCTION.

The following Discourses were published separately immediately after their delivery, at the request of the General Agricultural Society before whom they were read. A reprint is now given of them collectively, at the suggestion of some of the members. The Author has availed himself of the occasion to make a few additions which further experience, or more correct information obtained, required.

The reader — should they be honoured by being looked into by others than those for whom they were first intended — will be pleased to remember that they were written, as their name, "Discourses," implies, for particular occasions, and as much for the purpose of endeavouring to promote inquiry on important subjects, and even more, than for imparting information to those who had studied the subjects.

It has been stated in the Preface to the pre-

ceding Lectures, that the formation of agricultural societies may be considered amongst the proofs of an increasing intelligence in the West Indies, and desire for improvement. The history of the societies which have been formed in Barbados corroborates this; and, further, the important fact, that so long as there was little inducement to exertion, little exertion was made; few or no improvements were attempted; and that the established system, excepting at intervals, having been remunerative, an easy content was commonly and naturally the consequence. The period alluded to was that which preceded the abolition of the slave trade in the British colonies. That important preliminary measure led reflecting minds to the consideration of its consequences, and to the persuasion of the necessity of adopting measures to meet them.

Under the incitement thus afforded, the first attempt was made to form an agricultural society in Barbados. It was instituted on the 8th of December, 1804, under the name of "The Society for the Improvement of Plantership." Its first president, who was also, it is understood, its founder, was Dr. Holder, a man of no common mind or scientific attainments. Its first secretary was Mr. Moody, the mathematical teacher in Codrington College, and who was its first ho-

norary member, now a Lieut.-Colonel in the Corps of Royal Engineers. Amongst the members, limited to thirteen, were individuals distinguished for their worth and abilities, most of whom have filled high public situations in the colony. The useful objects of the Society were but very imperfectly denoted by its designation. From the minutes of its proceedings which are now before me, from its foundation to the year 1816, for which I am indebted to the liberal kindness of Captain Senhouse, R.N., and of Dr. Clarke, it appears that the culture of the land, in its widest acceptation, had their attention, and equally the care and improvement of stock, inclusive of slaves.

In their minutes, a great deal of useful information is brought together, partly in written communications, partly the results of the experience of the members communicated in conversation. On the condition of the negroes, their diseases, and decrease from the deaths exceeding the births, with suggestions of a remedial kind, there are two important papers; one contributed by Dr. Jones, who had acquired early and lasting fame by his researches on the arteries; the other by Dr. Caddell, then an eminent practitioner in Barbados. Both contributors are equally distinguished for the humanity displayed, and for

the medical knowledge. On the same subject there is an excellent report of a committee, also remarkable for humane feeling and strong good sense in the measures recommended, likely to render the negroes more healthy, cheerful, less addicted to vice, longer lived, and more prolific.

That the society was of eminent use can hardly be doubted. It appears to have set the example, to have led the way in every kind of improvement, such as the greater use of implemental husbandry, greater attention to the cattle, to the rotation of crops and the growing of provisions, to the making and applying of manures, to the improvement of the public roads, and to the private roads of estates, to the manufacturing processes in the instances of sugar and rum; and, most of all, in attention to the negroes,—an attention that was rewarded by their preservation, then a matter of paramount concern, and to which competent judges attribute in great measure the abundant supply of labour Barbados now possesses. It is worthy of remark at the same time, that their efforts on the score of improvement towards the negroes were characteristic of the time and of the slave condition of the people. Considered as stock, much the same rules were inculcated for their amelioration as for

any other species of stock. Better food was proposed for them, better clothing, less severity of work, kinder treatment, the establishment of estate infirmaries and nurseries, and the having the best medical advice ; but no suggestions were offered for the opening of schools, for attendance at church, for the aid of the ministers of religion; in brief, not a single measure was suggested directed to the culture of their minds. The efforts, as before mentioned, had solely in view the ameliorating of the animal condition, the preservation of health, and their increase. Even these exertions in favour of the slaves barely attained the object in view; they seem merely to have succeeded so far as to stop the excess of mortality over the births, and the preservation of the race, the extinction of which, as already observed, was then matter of apprehension.

This society continued in existence up to a late period. It was dissolved, about five years ago, and in consequence, it is understood, of some of its most influential members having returned to England. Its early period, as commonly happens, the period of its youth, was that of its energy and greatest usefulness, when the minds of the members were fresh and unexhausted, their hopes sanguine, and disappoint-

ment unknown, with an ample rich field before them for their labours.

The next society formed was that of St. Phillip's District Agricultural Society. It was commenced in 1843. The originator of it was W. M. Howard, Esq., who long presided over its interests, and who on resigning the office of president, after taking up his abode in a distant parish, was honoured with a public dinner, in acknowledgement of the able manner in which he had performed his presidential duties.

This society was, it is believed, also eminently useful, especially, like the preceding, in its early exertions, and particularly those directed to ameliorate the condition of the labourers as men, as thinking, responsible, moral beings, a part of the community, in contradistinction to what they had previously been considered, that is, before their emancipation from slavery. In these exertions, the interests of both parties, the proprietors and labourers, were attended to, on the sound principle that they cannot be disunited without injury to both classes.

The third society that was instituted was that of St. Thomas's District Agricultural Society, already alluded to, under the presidentship of John T. Ellis, Esq. It was commenced in March, 1845.

The fourth in succession as to time was that of

the General Agricultural Society, which held its first half-yearly meeting in June, 1846, presided over by the then President of the Council, the Honourable J. Ryecroft Best, a gentleman distinguished for his independant public spirit, and one of the leading members of the first agricultural society.

The society last formed, viz. in the year 1846, is that designated the District Leeward Society, composed of gentlemen chiefly residing in the parishes St. Lucy and St. Peter, constituting from their position a district almost apart. Its president is the Honourable Dr. Goding, distinguished by his scientific acquirements; its treasurer is Mr. Briggs, a gentleman who has deservedly acquired a high name as a skilful and successful planter, and one to whom the agriculture of Barbados is under no inconsiderable obligations, on account of the improved methods which he has been instrumental in introducing. Nor should mention be omitted, that the founding of this society was chiefly owing to the suggestions of Dr. Phillips, whose writings on tropical agriculture have been so well timed, judicious, and useful.

The plans and objects of the three District societies have been very similar, and also very similar to those of the first society, the rules of

which they have generally adopted.* The meetings have been monthly, taking place on the estates of the several members in succession, nearly an entire day being devoted to the occasion. The first duty is the inspection of the estate throughout, the examination of the crops, of the cattle, and of the works. This is performed by the members generally, who commonly

* According to the printed rules of this society, formed on its institution, its members were to be confined to gentlemen who superintended or took a part in the management of their own estates; their meetings were to be monthly, at each other's houses in succession, commencing at seven o'clock, assembling to breakfast, dining at three. The order of business was: "1st. To ride round the estate of the entertaining member; 2ndly. To discuss the topics previously agreed upon (having in view a complete system of management); to communicate the results of experiments, and to determine upon those of the succeeding meeting; 3dly. To read and discuss the communications received by the society; 4thly. To converse on such subjects as the examination of the estate will naturally produce; 5thly. To settle private business." In addition, some time after a report was made on the condition of the estate on which the meeting took place, its merits and defects, with suggestions, when needed, for its improvement. There were no subscriptions, but there were fines for nonattendance of members, if not reasonably accounted for in writing. There was no restriction as to the election of new members, on vacancies occurring, on account of locality. The society was the agricultural society of the island, and exercised an influence throughout the island of a beneficial kind.

assemble about eleven o'clock. It is followed by an examination by an appointed committee of the proceedings on the estate, the amount of labour, the cost and kinds of manure, the quantity of provisions grown, of sugar, rum, and molasses made, with other particulars relating to management. Founded on this inquiry, a report is drawn up by the committee embodying the results, expressing their opinion thereon, good or otherwise, as they may decide on the several particulars. The report is read by the secretary to the assembled members; and some discussion commonly follows it. Papers on agricultural subjects, when submitted by members, are next read, and their subjects discussed; or subjects proposed for consideration at a former meeting are considered and discussed. An early dinner follows, commencing generally at five o'clock; and the party commonly separate about eight. Strangers and honorary members are generally invited to the party, and in the St. Thomas and Leeward Societies are not partakers merely of the good cheer of the dinner-table, but, what is better, are present at and may take a part in the preceding discussions. Yet the dinner is not to be spoken of disparagingly. It is hospitably and liberally conducted, and in good taste, in the West Indian manner, various plates of tropical fruit, with flowers, being intermixed with the dishes. The after part is the

most marked part, which is also of a very miscellaneous nature ; now a health is drunk, now a discussion is entered upon regarding some agricultural subject of interest, which a toast may have given rise to, with the occasional interruption or interlude of a song. One meeting of the twelve, the anniversary, is commonly more formal than the others. Then the yearly report of the Society is read, giving an account of its proceedings, a report which is published, and to which is appended the papers that have been contributed.

The General and Agricultural Society, besides the president and ordinary officers, has a council, the managing body, formed of a certain number of its members. Many of the members belong to the district societies. As the objects of the latter are chiefly local, so those of the general society, as it name implies, relate to the agriculture of the island at large. The half-yearly meetings it was intended should take place in different parts of the island, and be accompanied by ploughing matches and exhibitions of cattle with prizes, to be concluded by a dinner. This plan was carried into effect at the three first meetings. On each occasion the governor, the patron of the society, honoured the meeting by his presence, and joined the evening dinner party. The two last meetings, owing to the depressed state of affairs, were so conducted as to entail no expense, and in conse-

quence the ploughing matches and cattle shows were given up for a time. The meeting assembled not on a distant estate, but in the Town Hall of Bridgetown, heard the report read, and such papers as were brought forward; an altered arrangement, it may be observed, strongly exemplifying that state of depression which led to it, and to which the island was suddenly brought, in common with all the other West Indian colonies, from various unfavourable circumstances co-operating.

The General Agricultural Society has provided a reading-room in Bridgetown for the use of its members, where the principal agricultural journals are taken in; where a library is forming, and a collection of agricultural instruments. Subscriptions, very moderate in amount, are paid by the members both of the district societies and of the General Society. The business of each is conducted gratuitously; no officer of either is paid. The officers of the General as well as of the district societies are a president, vice-president, treasurer, and secretary; and, in one or two, a corresponding secretary as well.

Such is a brief sketch of these societies and their meetings. That they have been of service in the cause of agriculture cannot be questioned. At the same time it may be admitted, that they have not done all the good that was perhaps too sanguinely expected from them. Hence some

disappointment has followed, and a result of that has been that some members have withdrawn; and at least one of the societies has not had the support it needed, and has fallen into a state of depression.

Surely this is to be regretted, especially at a time like the present, when such societies, if vigorously conducted, ought to be most useful. Besides their utility in relation to agriculture, are there not other ways in which they are, or may be, useful — socially, politically, morally? They bring together men of varied experience, of different views and sentiments; knowledge is communicated and exchanged in conversation; a friendly social feeling is engendered and kept up; generous sentiments are expressed, and an elevating tone of feeling is promoted. No where have I ever heard the true interests of the labourers better supported than at one of these meetings, with the desire of improving their condition as men, morally and intellectually viewed. And nowhere have I ever witnessed so little disposition to adulation, and a greater regard and respect, and generosity in expressing the feeling to departed merit, as instanced in the case of the ex-governor-general Reid. I say departed; an ex-governor, be it remembered, in the colonies, being, in relation to their interests, little different from one deceased.

Farther, I am confident that these societies are useful, and have been eminently useful, in exciting to inquiry, in calling forth the energies of young men, and in imparting to agriculture a scientific and higher character in consequence, than if followed merely as an art. The papers that have been contributed lately to the "Agricultural Reporter," as well as those which have been read at the meetings of the several societies, may be added in proof of the correctness of these remarks. In one of the last numbers of the "Reporter" the subject of wide planting is so treated by a young agriculturist, a member of St. Thomas's Agricultural Society, in which the principles of science, even as regards the formation of dew from radiation, are brought forward in support of the improved views which he advocates; and other like examples might be referred to.

It is almost a truism to observe, that the condition of a community is most strongly marked by its moral and intellectual state; that that society in which most of mental energy and ability is exerted, — where the arts and sciences are most advanced —the indications of such exertion,— in which morals are purest, the virtues most active,— must comparatively stand high in influence, happiness, and prosperity; — and *vice versâ.* It is the mental culture — moral, religious, intellectual,

which mainly distinguishes one period from another. Such culture is the great desideratum in the West Indies; and these societies have not, I am confident, been inoperative in breaking ground, and making a beginning in the important labour. A new era, it is to be hoped, is opening in the West Indies, in relation to society, its desires, and wants, and attainments, — when the main consideration will not be material wealth and the fleeting pleasures of sense; when life will be more rationally passed by the majority, and more moderately than heretofore, with more of comfort, of refinement, and of real enjoyment; and when the advantages of the few will not be almost exclusively considered, but the good of the whole; and, lastly, when the distinction of colour— established during slavery — will be abolished, and that of merit rather, so far as the imperfections of human nature permit, be substituted for it. And that such hopes are not entirely baseless, it is believed may be inferred from the circumstance, that, even as thus strongly expressed, they will not be considered by reflecting well-disposed persons who have watched the progress of events during the last fifty years, as by any means visionary and Utopian.

FIVE DISCOURSES

DELIVERED BEFORE THE

GENERAL AGRICULTURAL SOCIETY OF BARBADOS,

DISCOURSE I.

ON AGRICULTURE IN ITS SCIENTIFIC RELATIONS.

GENTLEMEN, — You having in your kindness done me the honour of making me a member of your Society, the least I can do to express my grateful feeling is to endeavour to aid in promoting the important object for which you have come together; viz. the advancement of Agriculture in Barbados.

A stranger amongst you, with little experience in the peculiar agriculture of the Tropics, and especially of the West Indies, it may appear presumptuous in me to come forward even in the manner I have mentioned to afford some little assistance in the common cause: I say it may *appear so*, but I trust only on a hasty view of the subject,—as besides experience in agriculture,—in the cultivation of certain crops empirically,—there is a knowledge connected with general principles, not of less importance, and which may, and ought to be, if not already, made available. The processes of art, I may remark, require

to be tested by the methods of science. It was by so doing that the late Mr. Watt was enabled to improve the steam engine, — the application of which to useful purposes has constituted a new era in human industry. Had that distinguished man been ignorant of the doctrine of latent heat, he could never have accomplished what he did;— he never could have perfected that instrument which, it has been calculated, with the machinery put in motion by it, in England alone, accomplishes work equal to the direct labour of at least 300 millions of men!

Lighting by gas affords another instance of the vast advantage to be derived from the application of scientific knowledge and methods to the processes of art. When gas was first employed for this purpose, as in the iron works of Lord Dundonald, — the father of the present Earl, — it was used in as rude a manner, — as ignorantly (that is in relation to the knowledge of its properties) as that is at present which issues from the earth, in this island, on the "Turner's Hall" Estate, well known by the name of the "Burning Spring." — It has been by an analysis of the gas, — by a careful study of its composition and properties, — and how adulterated as obtained from different sources, — the result of scientific, chemical enquiry, that illumination by means of it, with the aid of mechanical science, has been brought to such great perfection.

Innumerable other instances might be adduced in illustration of the close intimacy that exists between science and art, and how the former is required for the perfecting of the latter; indeed, I believe this is now so generally admitted, that to most of my audience it may have appeared unnecessary to have adverted to it: and yet I think it is necessary in regard to agriculture, because science has hitherto been only partially applied to agriculture; and least of all, I believe, has it been applied to Tropical agriculture. In agriculture, as yet, we have had no brilliant example, as in the instance of the steam engine, — as in the instance of the preparation and use of gas, — of the benefits to be derived from such application. And hence, perhaps, some hesitation and degree of doubt in the minds of those who have only experience, and handed down knowledge in agriculture, and have not applied their minds to the study of it as a science, — *i. e.* as a connected system of knowledge, — a generalisation of facts methodically arranged, — or of doctrines and principles deduced from facts, — so classed or methodically arranged.

In this discourse, my aim will be to draw your attention to the connection of science — chiefly chemical science — with agriculture, — to show how the one may be turned to the account of the other, — and to impress on your minds, that to

attain eminent success, and pursue agriculture with satisfaction, it ought to be studied as a science, and practised on scientific principles; or, in other words, on rational methods, in contradistinction to those which are merely empirical.

Your indulgence I must ask in entering on the subject, for the task I have undertaken is not without its difficulties. I am limited as to time; I shall be obliged to be concise on many points; to take no notice of many things, which it might be desirable to notice and dwell on, for the purpose of elucidation, and to restrict myself almost entirely to elementary views, and to the peculiarities of local circumstances, bearing on the agriculture of this island. Limited as I am in regard to time, as I have said, this appears to me the method which it is best to adopt in addressing you on this occasion, the most fitted to bring the subject under your notice, in a manner promising to be the least wearisome, with the best chance of being in some degree useful.

Production is the great object of agriculture. To raise profitable vegetables from the soil is its main intent. The problem always for solution is, how this object is to be effected with greatest ease, with most economy, with most profit.

To study this according to the methods of science, we should first consider the elements which are concerned.

All vegetable substances, we learn from chemistry, are composed of comparatively few ingredients; these are chiefly carbon, oxygen, and hydrogen, with which nitrogen in some instances is associated, and with which are associated, in different instances, particular earths and salts.

The soils in which vegetables take root, by which they are supported, and from which in part they derive their nourishment, we learn also from chemistry, are composed likewise of a few principal elements, as of a few earths or metallic oxides, viz. alumine, silica, lime, and magnesia, variously intermixed and combined and in different proportions, associated more or less with oxide of iron, and certain salts, as phosphate of lime, sulphate of lime, and a few others; and are, according to certain admixtures of elements — the presence or absence of one or more of these ingredients — either favourable or unfavourable to vegetation — fertile or barren.

The atmosphere into which vegetables rise and spread, and from which also they derive part of their nourishment, we learn likewise from chemistry is composed of even fewer principal ingredients than the soil, viz. of two, oxygen and azote, in almost constantly the same proportions; with which are mixed, in variable proportions, water in the form of vapour, the immediate source of rain, carbonic acid, the chief source of vege-

table carbon, and ammonia, the supposed principal source of the vegetable compounds containing azote; not to mention other substances which are occasionally if not constantly present in the air, the existence of which there, is matter of inference rather than determined by the result of experiment.

Such is a very slight sketch of the principal elements concerned in the growth of vegetables, considered in relation to their composition and the sources whence derived.

Let us now draw nearer home and approach the subject more closely; let us give our attention to the principal, the supporting crops of this island; the qualities of the soils of the island in connection with its geological structure; and to the qualities of the atmosphere.

The sugar cane, sweet potato, yam, Guinea corn, maize or Indian corn, these are the principal crops of Barbados; the first, the cane, the staple for profit, the others auxiliary for food, in the way of rotation.

What is the composition of these different plants in their mature state, when fit for their respective uses, and to be removed from the soil? Let us begin with the sugar cane. In relation to our subject, it may be considered under two heads; its saccharine juice, which is contained in cells

in the stalk, like honey in the honey-comb; and the stalk, leaves, and roots.

The juice, it would appear, besides sugar and water, its principal constituents, contains, as it is commonly obtained by pressure, some vegetable acid, and a portion of leaven, or albuminous matter — an important substance both for profit and loss, the fermentation essential to the production of rum depending upon it, and likewise that unprofitable fermentation which so often takes place in molasses and sugar after shipment, and in the former even before. Viewed in regard to the ultimate elements of the juice, it has been found to be composed of such as exist in the atmosphere, and may be derived from the atmosphere, pure sugar being formed of carbon, hydrogen, and oxygen; the vegetable acids of the same, with a larger proportion of oxygen, and albuminous matter of the same, in different proportions, with the addition of azote. The products from the saccharine juice, unrefined sugar, molasses, and rum, the elements of which do not essentially belong to the soil, are the only exports from this plant, the only portions sent out of the island; and as regards the materials of the agriculture of the island, no loss, or a very trifling one, need thereby be considered as sustained.

The roots, stem, and leaves of the cane consist chiefly of woody matter, itself composed of the

same ultimate elements as sugar, and in the same proportions, but, it must be inferred, differently grouped. Mixed with the woody part are other matters, of which at present we have but an imperfect knowledge, either as regards the exact state in which they occur in the plant, or the part they perform, the use they are subservient to, in its growth and elaboration. This we know, that on burning the cane, a considerable portion of solid matter is obtained, the ingredients of which we infer, as they existed in the vegetable, may have formed a part of different vegetable compounds, and may have had a special use in regard to the well being, the prosperous condition of the plant. The principal of these solid ingredients constituting the ashes of the cane, would appear from chemical analysis to be silica, phosphate of lime, lime, magnesia, and potash. The design of the silica is obvious, to give firmness and due strength to the stalk and leaves. As concerns the use of the phosphate of lime, and the lime, and magnesia, perhaps at present conjectures only can be offered. They may answer the same purpose as the silica, helping to impart strength and give support, after the manner of the bones of animals, of which they are the chief constituents; and one or other of them may also be useful in disposing to the formation of sugar. Contrary in their nature to the elements of the saccharine juice, fixed in the

fire, and therefore forming ashes, we know that they cannot be derived from the atmosphere, that they can be derived only from the soil; and consequently, if they are not returned to the soil, it must sooner or later be exhausted of them; and being incapable of affording these necessary materials of the cane, so far it must be unfit for its growth, and barren. On the contrary, if they (the inorganic parts) be restored to the soil in the form of ashes, leaves, and the refuse of the distillery, all the silica, and potash, all the phosphate of lime, lime, and magnesia, will be given back to it, with a great increase of carbon in the unburnt leaves, and probably some considerable increase of azote in the distillery refuse, in which I have found, on examination, no inconsiderable portion of ammonia. These things duly kept in mind, the cane, under existing circumstances, should not be held to be an exhausting crop, — and should not be allowed to be so; and that it is not so of necessity, is fortunate for your agriculture; and if taken advantage of, cannot fail (if there be science in agriculture, as there unquestionably is, and use in principles) to conduce greatly to its prosperity.

Let us next consider the composition of the vegetables subordinate to the cane — those already mentioned cultivated for food, and in the way of rotation.

1st. *Of the Sweet Potatoe.* — I have incinerated the leaves and the bulb of this plant, and have examined the ashes. The ashes of the bulb I have found to consist of phosphate of lime, with a little phosphate of magnesia, of carbonate of magnesia, with a little carbonate of lime, of sesquicarbonate of potash, with a minute portion of sulphate of magnesia, and of sulphur, — without any silica. The ashes of the leaves were found to be composed chiefly of phosphate, and carbonate of lime, and of carbonate of magnesia, with some sesquicarbonate of potash, and sulphate of magnesia. The proportion of ash yielded both by the root and leaves was considerable. The sweet potato, it is deserving of remark, contains a certain proportion of albuminous matter, and consequently azote is an essential ingredient; and the sulphur, probably, is an element of its albumen.

2d. *Of the Yam.* — In the ashes of its tuber, I have detected a large proportion of carbonate and phosphate of magnesia, with some sesquicarbonate of potash, a little phosphate of lime, sulphate of magnesia, and a trace of silica. In the ashes of its leaves and stalk, I have found a good deal of carbonate of lime, with a little carbonate of magnesia, a pretty large proportion of phosphate of lime, with a trace of silica, and sulphate of lime, and some sesquicarbonate of potash, with a little sulphate of lime and sulphate of magnesia.

3d. *Of the Guinea Corn.* — The head, including the grain, incinerated, yields a good deal of ash, which I have found to consist chiefly of phosphate of lime, and phosphate of magnesia, of silica, and sesquicarbonate of potash, with a little silicate of potash. The stalk, also, on incineration, yields a considerable quantity of ash, of a very mixed nature. Its chief ingredients are phosphate of lime, carbonate of lime, and carbonate of magnesia, silica, with some sesquicarbonate of potash, and a little muriate of potash, sulphate of magnesia, and sulphate of lime.

4th. *Of the Indian Corn.* — The ash of this grain, which is obtained with great difficulty, owing to peculiarity of composition *, I have found to consist chiefly of phosphate of magnesia in large proportion, and phosphate of lime in a much less proportion, with some free phosphoric acid, and a trace of iron, — without silica, and without any alkali. In the ashes of the stalk of this corn, I have found a notable quantity of silica, sesquicarbonate of potash, phosphate of lime, and carbonate

* The peculiarity above alluded to is the ready fusibility of the fixed ingredients of the corn, owing to which in the first process of combustion when it is charred, these ingredients melting and enveloping the charcoal, defend it from the action of the oxygen of the air, and so prevent its combustion, —which readily takes place after their removal by the solvent power of an acid.

of magnesia; and I have detected the same ingredients in the enveloping leaves of the stalk, with this exception — that their ash has contained no carbonate of lime, but a pretty large portion of carbonate of magnesia.

These results show a considerable resemblance of composition in the ashes of the sugar cane and of the sweet potatoe and yam, of Indian corn and Guinea corn, especially as regards phosphate of lime; and in the instance of the stalk of the Indian and Guinea corn, silica. These ashes are the inorganic elements of the several plants, and we may infer are as essential to them, as the ashes obtained from wheat and the straw of wheat are to the wheat crop; and consequently, that, as regards their effects on the soil from whence they derive these inorganic elements, they are all more or less alike exhausting. Whether the points of difference in the composition of the several ashes, which in relation to the soil do not seem to be very important, should modify this conclusion; whether the depth to which the roots of the different plants spoken of, and the direction taken by them in growing, should modify it, I cannot pretend to offer an opinion. Very minute and careful enquiry, I apprehend, is required to be made, before an opinion on the subject can be given, that will be satisfactory. That these crops have the exhausting effects which the results I have given

indicate, is, I believe in accordance with the experience of some of the best agriculturists of Barbados, and is beginning to be acted on by many. The subject unquestionably is of very great importance, and I beg to recommend it to your attention, for examination, without bias. If the crops referred to are exhausting in the manner supposed, what are we to think of the excellence of the soil that is tasked, or, of the mistaken views of the planter who tasks it by crops in succession without rest, of the sugar cane, Indian corn, and sweet potatoe. During the ten months I have been in Barbados, I have seen from the same piece of ground, three harvests of Indian corn; and *that ground* is now under canes. In Antigua, where a system of rotation is little practised, the produce of sugar is, I believe, much larger than here; three hogsheads per acre is common, and four or five not uncommon, and from soils similar to some of this island. The economical question to which all agricultural problems of this kind, I apprehend, must be brought, is, are the intermediate crops, whether of corn or potatoes, of a value more than equivalent to their exhausting effect on the soil, supposing their effect to be proved to be such; and whether it would not be more profitable to renew the cane, using manure, than to grow the other crops without manuring.

Let us now turn our attention, and it must be

very briefly, to the geology of the island and the chemical composition of its soils, from whence the inorganic elements of your crops are derived.

Geologically viewed, Barbados may be considered as consisting of two well-marked regions, very different from each other in the features of the country, in manner of formation, as it must be inferred, and in the nature of the materials of which they are constituted. The larger portion rises from the sea by successive terraces, broken more or less by rents or gullies with transverse valleys or table lands, in which are innumerable cavities and basin-like hollows or depressions, giving the idea of its having been modelled under water by currents, and of having been raised from the bed of the sea, in which it undoubtedly once was, and that by a force acting continuously and regularly. The smaller portion descends to the sea from a central height, divided by valleys and hills; a miniature alpine country, each valley with a continuous descent, uninterrupted by gullies, and without depressions or basin-like hollows. This smaller region seems as if formed in a different manner from the preceding—as if raised by a force acting violently, by which it has been thrown up so as to appear in its present form; and on examination its strata appear to be in accordance.

The larger region consists of nearly horizontal

beds of calcareous marl and of calcareous sandstone and freestone, abounding in many places in sea-shells and coral, and resting on clay. The smaller region consists of strata of chalk, of different kinds of clay, and of different kinds of sandstone, mostly siliceous, with strata of volcanic ashes intermixed, and occasionally beds or seams of bituminous matter and coal. These several strata are more or less inclined; in some instances they are almost vertical. And with the exception of certain of them that abound in the siliceous skeletons of microscopic animalcules* (infusoria), they contain very few organic remains.

In regard to age, all the circumstances of the smaller district indicate that its strata are of greater antiquity than the beds of the larger. Coral rock, or what is analogous to it, caps some of the heights of Scotland; the top of Bissix Hill is a calcareous freestone, containing shells, spines of echini, and teeth of two species of shark.

It would occupy too much of your time to enter into further particulars relative to the geo-

* Since these remains were first observed by the author, portions of the chalk-like beds above alluded to, in which they occur, have been examined by M. Ehrenberg of Berlin, who has detected in them a large number of species, and some genera, not before known.—See *Sir Robt. Schomburgk's History of Barbados.*

logical structure of this island, so peculiarly interesting, so deserving of attention, both as regards the causes which have acted and of which it is a manifestation, and the promises it holds out of usefulness in the extraordinary variety of its materials, applicable in various ways, and especially to your agriculture, such as the marl of one portion and the clays and chalk of the other. I shall briefly return to these applications after noticing the soils.

The soils of Barbados, I believe, may be included in its general geological history. I have very little doubt that they have all been deposited from water, and at a time anterior to the elevation of the foundations on which they rest, when these were in the bed of the ocean. The soils generally, whether in the valleys of the terraced part of the island, or in those of the hilly region, consist principally of the detritus of the older or crystalline rocks, such as form at present the mountains of the adjoining continent: they consist chiefly of clay (itself very compounded) and of very fine siliceous sand. This, I can assure you, is generally the case, so far as I can judge from the examination I have yet made of specimens from different parts of Barbados. The only marked exception I am acquainted with, is where a bed of marl constitutes the surface, or where the substratum is of chalk, and there the soil is chiefly calcareous,

though not invariably so. Such a constitution of soil, I may remark, is a most happy circumstance for your agriculture. From its nature, viewed in relation to its organic materials, it may be considered inexhaustible, and admitting of improvement (if defective) with great facility. In the clays and sand, derived from the wear and decomposition of crystalline rocks, we are sure there is a store of the most important elements essential to the growth of vegetables, as, besides the common earths, silica, alumine, lime, magnesia — besides these, there must be potash and soda, and the phosphoric and sulphuric acids.

In the marl and chalk, phosphate of lime, I find, is easily detected, and is an almost constant accompaniment. Every tree that grows is a proof that the vegetable alkali, potash, is present in the soil. Take the instance of a tamarind tree; without culture, without manure, year after year it yields fruit abundantly, and in that fruit, as you are well aware, potash, in the state chiefly of cream of tartar, exists in large proportion, the alkali of which it can extract only from the soil.

The composition of the soils of Barbados, it appears to me, without exaggeration, is a subject for gratulation, cheering and hopeful in a peculiar manner. Truly it seems as if this island were designed by nature for what it now is, the garden of the sugar cane; the essential elements, the

inorganic, being so plentiful in the soil; silica rather in excess than deficiency, and comminuted by an expenditure of force which, could it be calculated by horse power, would doubtless be very startling; and phosphate of lime in large quantity (in proportion to what is required), which can be made available, existing in marl and chalk, and, I may add, in the sea-sand of the greater portion of your shores, and also, I believe in the subsoil clay, in which, in the two or three instances I have sought for it, I have not failed detecting traces of it. To mention an extreme instance, even in the apparently barren sand of "Chalky Mount," which is chiefly siliceous, I have found the same essential inorganic elements of fertility, and lime and alkali, with phosphate of lime.

The last part of my subject to which I beg to call your attention is the atmosphere—that great storehouse of the elements of the organic parts of plants, as the earth is of its inorganic.

I have already mentioned generally the composition of the atmosphere, how formed, chiefly of two gases, oxygen and azote, with which is mixed a minute quantity of carbonic acid, and a variable proportion of water in the form of aqueous vapour. And besides these, it must be inferred that other substances are present in minute portions, as already observed; all substances, in brief, that are capable of rising into the air in vapour,

or of being suspended in it, owing to their lightness, from the fineness of their particles, such as are the motes which we see in the sun beam, or the saline matter derived from the spray of the sea. Of vaporable substances, one perhaps of the most important, in relation to agriculture, is ammonia. Whenever animal matter undergoes decomposition, ammonia, or the volatile alkali, a compound of azote and hydrogen, is produced, and passes into the atmosphere in union with carbonic acid as a carbonate; and being soluble in water is restored to the earth in every shower that falls. This, at least, is what happens in Europe; there, whenever rain has been examined, a minute quantity of this alkali has been detected. Whether it exist also in appreciable quantity in the rain water of the tropics remains to be determined. It will probably be found to be present even in the rain which falls when the trade winds prevail, winds blowing over a vast space of ocean; but it is also probable that it will be found here in less quantity, and will be more difficult to detect than in England, France, or Germany, where the sources of putrid exhalations are so many more and so various.

The connection between these, the elements of the organic parts of plants derived from the atmosphere, and those of the inorganic, existing in the soil, is very admirable. Rain, without which

we know there is no active vegetation, brings to the earth, dissolved in water, some carbonic acid, some oxygen and azote, and, we will infer, a portion of carbonate of ammonia. Absorbed by the soil, this rain water, so charged, dissolves what is soluble which it comes in contact with, carbonate of lime, phosphate of lime, the vegetable alkali, silica, and other ingredients fitted to enter into the composition of plants. This compound solution may be considered as the elaborated food of plants, to them what chyme or even chyle is to animals. It is drawn in by their minute spongy roots, ascends in progressive change as sap, passes into the green leaves; and is there exposed to the action of light, exhaling oxygen and fixing carbon; and in its circulation from the leaf, exposed to the influence of various tubes and cells, it, by a process analogous to secretion, administers to the growth of the vegetable in its vast variety of forms, in this great department of Nature.

The sugar cane is a striking example of what has just been stated. We have seen that the greater part of this plant in its mature state consists of elements such as exist in the atmosphere, and which we are sure have been derived from the atmosphere, either directly, chiefly brought down in rain, or indirectly, from vegetable manure. I am informed that an acre of land planted with canes will yield, under favourable circumstances,

100 tons of vegetable matter. What an immense increase is this? What an immense quantity of carbon is thus separated from carbonic acid (for, every particle of woody fibre formed, every particle of sugar formed, implies such a separation); and what an immense evolution of oxygen! The one as necessary to vegetable life and growth, as the other is to animal life.

The connexion of the atmosphere with the soil, and of both with manures, is indeed admirable. Whilst the soil receives and condenses atmospheric air, and favours the formation of ammonia by the union of azote with hydrogen in its nascent state arising from decomposing vegetable matter, its clay or aluminous portion combines with certain vegetable matters, retains them for a time, and allows them to decompose slowly. Manures generally, in accordance with this, act by yielding a greater plenty of food to plants, than the soil with rain alone is capable of affording; in consequence of which feeding, they grow more rapidly and more luxuriantly. But let it be kept in mind, that if the soil contain the inorganic elements required, then no *new element* is supplied through manures; let it be kept in mind, that the vegetable part of the manure acts chiefly by yielding carbonic acid, and the animal part chiefly by yielding ammonia, and both by yield-

ing certain inorganic elements, which had previously existed in the soil.

I stated in beginning, that I should be obliged to restrict myself to almost elementary views: this, you perceive, I have done; omitting even to allude to many important points, deserving of careful inquiry in connection with the interests of agriculture: I shall notice a few only in the briefest manner as examples; such as, what are the precise peculiarities of *this* soil or *that;* one specially favourable to the growth of the cane, the other not? What are the peculiarities in the composition of the ashes of the best canes, *i. e.* of those which yield the richest and purest saccharine juice; are they alike in composition, or variable? And if variable, what is the *constant* circumstance, on which it may be inferred the superiority depends? Do the best canes contain a *large* portion of albuminous matter, or a *small* one? And, in connection with this question, are animal manures on the whole most favourable, or purely vegetable, or a mixture of the two, to the growth of canes of the first quality? These, and many more problems, I apprehend, must be solved, before your agriculture can be admitted to be founded on a scientific basis, and conducted on scientific principles.

Gentlemen, I must here draw to a conclusion, for I have occupied enough of your time: I thank

you for the attention you have been so good as to give me. As I have congratulated you on the excellent qualities of the soil of Barbados, so let me do the same on the peculiar advantages of agriculture, viewed as a pursuit or profession. What other profession is there in which there is so much scope for emulation, free from painful contention; in what other, such inducements to union and cooperation! The success of one planter does not interfere with the success of another. The world is, or should be, the market of your produce. Four agricultural societies already have been formed in this island, with one common object in view. Of what other profession can the same be said! Lastly, if we consider agriculture as a science (though in its infancy), a rational system of culture, the basis of which is vegetable physiology and chemistry, I think I may congratulate you further in having a most interesting as well as important subject for inquiry, worthy of the exertion of the highest intellect, and which, we may be sure, will reward every one who exercises on it an inquiring and observing mind.

Even as an art, we well know, agriculture has always been attractive, yielding occupation peculiarly pleasant and wholesome, with unceasing change, with unceasing occasion for hopes, for fears. How much more attractive ought it then

to be, when the interest derived from science is added to it; that *kind* of interest which is connected with the exercise of the reasoning powers, the comprehension of the operations and changes which we are daily witnessing, *and by comprehending them,* having the knowledge which is power, *being able in some measure to regulate and controul them,* for certainly this is what *should be aimed at and will be attained,* when the science of agriculture is advanced.

I have spoken of the soils of the island, as generally differing little in their principal and most obvious ingredients. Minute differences, however, undoubtedly do exist in them, some of which may be important.

My official duties allow me but little leisure; that little I would willingly, in part, apply to do what I can to determine such differences; accordingly I shall be glad to receive examples of any soils, considered any wise peculiar for examination, and I indulge in the hope, that at your next meeting, or at furthest the subsequent, it may be in my power to communicate (should it be the wish of the Society), the results in a short discourse on the peculiarities of the soils of Barbados, considered in relation to their chemical composition and their productive powers. To give any information on the latter point, of course

I must be indebted to the gentlemen who may be so good as to contribute the specimens of soils. Were a memorandum to accompany each sample, in which were to be specified how the soil is peculiar, to what vegetables or crops favourable, to what unfavourable, the value of the chemical examination would be enhanced; and perhaps some useful practical conclusions might be arrived at, and an example thence immediately afforded of the advantages of this mode of inquiry, that is, of the application of Chemistry to Agriculture.

DISCOURSE II.

ON THE SOILS OF BARBADOS IN CONNECTION WITH THE CULTURE OF THE SUGAR CANE AND OF OTHER CROPS.

Gentlemen, — At your last meeting I had the honour to address you on the subject of agriculture generally, considered in some of its scientific relations; I now propose to endeavour to perform the promise I then made; and with your leave, call your attention to the soils of Barbados, which, as the basis of your agriculture, cannot be too carefully studied, cannot be too thoroughly known — and such thorough knowledge, I need hardly remark, can be acquired only by minute and accurate examination.

I shall first speak of the soils of the island generally, so far as I have yet had an opportunity of observing them; — secondly, of the qualities of those varieties of soils which are most strongly marked; and lastly, I shall venture to offer a few remarks, as suggestions, on the admixture of soils, and their treatment, with a view to amelioration in certain instances in which there are glaring defects.

On this occasion, as on the former, I shall have

need of, and have to ask your indulgence, — for the subject I am entering upon is a large and difficult one; I have not the advantage of a practical knowledge of it; the views — the information I have to offer, are more of an abstract kind than practical men commonly like, or are disposed to confide in; but being founded, as I believe they are, on scientific principles, and addressed, as I trust they are, to a scientific audience — that is, to an assemblage of well-informed men, convinced that science is essential in agriculture to promote its improvement and give it its highest degree of perfection — I am confident I have not to ask your indulgence in vain.

Commonly, there is a certain connection observable between the geological structure of a country and its soils. In a large number of instances this connection is most intimate; so that the rocks constituting the hills and mountains being known, the soils of the plains and vallies may be predicated with considerable accuracy; and for this obvious reason, that the latter, by a process of decomposition and disintegration, are derived from the former. This is remarkably the case in primitive countries, in which the existing soils appear to be formed almost entirely by the processes alluded to. Occasionally, however, it is otherwise; there are countries in which there is no immediate relation — at least of dependency

— between the soils at the surface and the strata on which they are incumbent, the soils not being derived from the rocky strata on which they rest. This is strongly marked in the instance of tertiary geological formations, — those in the history of our globe of recent origin, — formed of the detritus of older rocks, brought down by rivers or thrown up by volcanoes, deposited in the ocean, there modelled by currents, variously consolidated and altered by additions of materials which they there receive, ultimately to be raised, by forces acting from below, into the common air, — to become islands, or parts of continents, according to situation. Some of the most fertile parts of the earth are of this description; the majority of the West Indian islands are such, and Barbados eminently so.

As regards the interests of agriculture, what I have just adverted to may be held to be a great advantage, as I shall farther on have an opportunity of pointing out; but as regards the study, the description, the comprehension of the soils of a country, it adds vastly to the difficulty, presenting as it does a subject of almost incalculable complication, instead of one of simplicity and uniformity.

In my preceding discourse, I took a hasty glance at the geology of Barbados — of its two parts so well marked by contrasts; the smaller

portion, formed of steep hills and descending valleys, consisting of beds of chalk, of various clays, and of various sandstones: the larger portion of terrace-like formation,—height rising above height, in long-continued ridges; table lands, or valleys of little depression intervening; with a foundation generally of calcareous rock or marl, abounding in shells and other remains of marine animals.

In the part or district first mentioned, there is observable more relation between the soils and the rocky substrata than in the second. Nor is this surprising, or inexplicable. Owing to the steepness of the hills there, their declivities are powerfully acted on by heavy rains, and there is a constant tendency to the denudation of their sides in consequence. Accordingly, in this part of the island, where chalk is the substratum, a white calcareous soil very little different from chalk is found at the surface; where a bed of clay lies beneath, the surface soil is found to be stiff and argillaceous; where sandstone is the basis, there the soil resting on it is often little more than sand. These remarks apply chiefly to the steep declivities of the hills; less so to the valleys, especially where they open out into little plains. There, there is found a certain uniformity of soil, which perhaps may be considered as a mixture of all the several ingredients of the higher regions, washed down by torrents and commingled. It is a well-

marked alluvial soil, abounding in siliceous sand, containing more or less of clay or alumine, with a small proportion generally of magnesia and lime; a soil not unlike that of British Guiana, being similarly derived, but I believe of a greatly better quality, the girding mountains of the interior of British Guiana being chiefly of granite, and there being no background there of fertile chalk, as here, to furnish a supply of calcareous matter, however small.

In the other and larger portion of the island, I have said, there is less relation between the quality of the soils and the rocky beds on which they rest. In many places, even on the same estate, there may be found a considerable variety of soil and subsoil; in one spot, a calcareous marly soil; in an adjoining one, a stiff clay; and near at hand to this, a loose light soil, containing a good deal of siliceous sand, and no small proportion of calcareous earth. The principal varieties of soils over this, the greater portion of the island, may be conveniently classed under a few heads, according to their composition, on which their nature and qualities depend, and in which, notwithstanding the remark I have just made as to admixture, some order of distribution is observable.

On the higher grounds a reddish brown soil is predominant, containing a large proportion of siliceous matter in a very finely divided state, with

a certain portion of clay, and an admixture, in small quantities, of lime and magnesia. This soil presents itself even at the edge of the cliff, bordering and bounding the smaller hilly region — a situation, we are sure, where it could not be brought after the ground on which it rests — coral and shell limestone—was raised from the depths of the sea, because there is no higher ground near, from which it could have been conveyed by the action of water. A striking example of this is to be seen at the top of Horse Hill, immediately above the road leading down to St. Joseph's Church. Of the kind of soil under consideration, excellent examples offer on the estates of Bloomsbury, Welchman's Hall, and Blackman's. These I particularise, because I have examined specimens of them, — for which I am indebted to their proprietors.

Another quality of soil is that which prevails between the terrace elevations, well marked in the valley of the Sweet Bottom, and, perhaps, less distinctly in the more expanded and extensive valley of St. George. It contains more clay than the first mentioned, a large proportion of silica and but a very small proportion of lime and magnesia. Its colour is variable, red and brown are its predominant tints in the higher grounds.

A third variety of soil is that which differs but

little from calcareous marl, is incumbent on a substratum of marl, consists chiefly of carbonate of lime, contains fragments of sea-shells, contains but a small proportion of clay and silica, and less of magnesia. It is generally of a light colour. It occurs in some parts of St. Philip's, especially its north-eastern part, in parts of St. Michael's and also of St. Lucy's, and probably elsewhere in many places.

A fourth variety is a dark soil, in some situations almost black, a colour which it owes to vegetable matter in a peculiar state of decomposition, approaching I believe the state of peat. This soil commonly contains a good deal of clay, with a sufficiency of calcareous matter and of silica and magnesia. It occurs most commonly in low situations towards the sea-coast, where there is little declivity, where the drainage in consequence is imperfect, and there is a tendency, when there is excess of rain, to stagnation.

I shall mention only one other variety of soil, a calcareous argillaceous marl of a grey colour, consisting of alumine, carbonate of lime and of silica in well-adjusted proportions with some carbonate of magnesia. The most remarkable example of it that I am acquainted with is on the Codrington College Estate, below the cliff, where, thrown up into steep hills and ridges, and depressed into narrow valleys and ravines, it forms a

little district apart, equally remarkable for the barrenness of its aspect, its real fertility, its abundance of water; all I believe depending on the same cause,—the nature of the soil and subsoil.

Other varieties of soil might be pointed out; but in a discourse such as this, with little advantage. They occur intermixed in one or other of the principal varieties I have enumerated, for none even of these, the principal varieties, are free from admixture to any extent. How few estates for instance, whether situated high or low, are without marl; how few are without deposits or beds of stiff clay, I am acquainted with one estate in St. Lucy's, in which there is a substratum of carbonate of lime, in the form of minute ovoid granules; of another in St. Michael's, in which the same substance is met with in the form of minute rhomboidal crystals uncohering, after the manner of sand; of a third in St. Thomas's, where adjoining a bed of calcareous marl is a deposit of siliceous earth in a very finely divided state, essentially different from, but in appearance perfectly resembling chalk. These may be considered as curiosities; but they are significant in their indications, and not uninstructive. In connection with the general geological history they seem clearly to prove, as I have already stated, that the soils of Barbados were mainly deposited when the rocky substrata

on which they rest were lying at a considerable depth in the ocean, where they were formed; and that the great variety of soils which are met with, must have been owing to the causes then in operation, rivers bringing down the detritus of the mountains of the continent, currents in the sea distributing them, and probably submarine volcanic eruptions, of which there are indications here, disturbing them and adding new materials to complicate them the more.

These may appear to some, theoretical views, and visionary; but they assuredly are not so. The reading of geological signs is commonly unambiguous and easy. Like the reading of a written language, it must be entered upon in its minute parts; these are, as it were, its alphabet. A sea-shell, the spine of an echinus, the tooth of a shark, the microscopic remains of infusoria, occurring mixed with water-worn particles, whether loose, as in beds of marl, or compact as in beds or strata of limestone, plainly declare their submarine origin. And other sources are not less clearly denoted by other appearances; the form of the minute fragments constituting volcanic dust and ashes is not to be mistaken, each little fragment, as seen under the microscope, presenting sharp edges and acute angles; and the form of river sand, especially of hard quartz sand, altogether different from the preceding, all the edges and

angles worn by attrition, is equally distinct and significant. Such geological interpretation is not merely amusing to the mind; it is valuable I believe in connection with agriculture, viz. by aiding to give, as it is well fitted to do, a true insight into the nature of soils.

The qualities of your soils, to which we will now proceed and give a brief consideration, as I have already observed, depend chiefly on the elements composing them. Of these qualities generally, two views may be, and I believe ought to be taken; one, as regards their texture, which is commonly called their mechanical or physical condition, as to the degree of sustaining firmness, of resistance to the implements of husbandry, of perviousness to air and water, and of power of retaining water; the other as regards their chemical composition, considered as the source of the inorganic elements essential to the growth of plants, and which, when of the best quality, should render the soils productive without aid from manures.

Let us now take a hasty review of the principal varieties of soil before named, in relation to these qualities.

1st. *Of the Calcareous or Chalk-Soil.* — This soil besides being composed principally of carbonate of lime, in a loose finely divided state with some alumine, contains a certain portion of

silica in the same state, also of carbonate of magnesia and of phosphate of lime, and doubtless of the vegetable alkali. From the nature of its constituent parts and the state in which they are, this soil, physically considered, may be held to be almost the perfection of a soil; cool from its colour reflecting the sun's rays, absorbent of moisture and not too retentive of it, allowing the rain to descend deeply into it and to be kept in store amongst its pores, to ascend and be exhaled as moisture on the occasion of drought, sufficiently firm to give due support to plants, and sufficiently yielding to be easily worked. These it must be admitted are excellent qualities. And as regards its nourishing power, through the medium of the inorganic elements which it is capable of supplying, its character is of a very high kind, as the elements which it contains are those which appear to be most essential to the staple and more important crops of the island, such as the sugar cane, Indian corn, yam, and others. This soil, with these excellencies, may I believe be held up as an *exemplar*. Its productive powers appear to be high. Without manure I am informed it will yield good crops and even of the sugar cane, and this successively for several years, without fresh planting; and it is worthy of remark, that the sugar, the produce of these canes, is esteemed above the average quality, and

is obtained in proportionally large quantity. The estimation in which soils of this kind are held is pretty well indicated by the rent which can be obtained for them, viz. from twenty-four to thirty dollars an acre, and even I believe occasionally as high as thirty-five; and this in situations commonly of difficult access, remote from the town, and having little but the fertility of the soil to recommend them, such as the steep declivities of Mount Hillaby, the highest part of the island, the chalky soil of which rising at least 1100 feet above the sea is cultivated to the summit; the rugged ground in the neighbourhood of Castle Grant; and that little district of similar ground, which has received the name of Irish Town.

The other calcareous soils of the island, in widely different situations, are more or less analogous to the chalk-soils, such as the marl soils already noticed, and the calcareous argillaceous soil of the Codrington College Estate; they have a great resemblance in their elementary composition, varying chiefly in the proportions of their constituent parts; and they are, I understand, all remarkably fertile.

2dly. *Of the Clay Soils.* — The qualities of these soils, as of clay soils generally, are strongly marked. It may suffice to describe them very briefly. They are retentive of moisture in a very remarkable manner, and at the same time little

pervious to air and moisture; liable to become indurated from drought, and boggy from excess of rain,—physically, great defects. Their composition, I believe, is somewhat variable; always abounding in alumine, never deficient in silica; they have most commonly a small proportion of lime and magnesia, especially of the former. Those clayey soils which have a greasy feel when dry, usually contain a good deal of magnesia. In their natural state, I apprehend that the bad preponderate over the good qualities which belong to them; but the reverse, in their improved state.

3d. *Of Sandy Soils.* — The peculiarities of these soils are the reverse of the last, being most readily pervious to air and moisture, and no wise retentive of moisture. Such is invariably their physical condition, whatever may be their chemical composition — a condition most unfavourable to fertility, and fatal to it, excepting under peculiar circumstances of situation, or seasons, — such as low situations where water is abundant, or where there is a substratum or subsoil retentive of moisture, or rainy seasons. Next to these circumstances, their composition is of most importance: those which are almost purely siliceous are almost barren; such exist in the parishes of St. Joseph and St. Andrew: whilst those which consist of comminuted shell and coral are, in favourable circumstances, fertile.

4thly. *Of Alluvial Soils.* — I have already spoken of the soil which occurs in the valleys of the hilly district, as an example of this kind, — that is, in the parishes last mentioned. The red soils of the higher grounds may also be considered as such; and even the greater part of the soils in the valley of the Sweet Bottom, and of St. George; and in brief, of a large portion of the island; in some instances the tendency being to an excess of the aluminous ingredient, with undue stiffness and tenacity; in some others — and I believe more rarely — to a deficiency of it, and undue porousness. The black soils, too, may be considered as belonging to them, exclusive of the peculiarity of colour, depending, as I have already mentioned, on a peculiar state of vegetable matter. Some of these soils appear to be excellent, in which the several ingredients are in a very fine state of division, and it may be inferred, duly proportioned — as in the instance of the Bloomsbury estate soil, and some others similarly situated; and also in the instance of some of those in the lower grounds, especially in the valleys of St. Andrew's and St. Joseph's. Generally, I apprehend, putting aside those of the highest quality, they may be considered as average soils, and from this circumstance, that they contain commingled the essential elements of good soils, and average also as regards their capabilities and produce.

Having thus taken a rapid glance at the qualities of some of the principal varieties of soils, I shall enter on the third part of my task, a brief consideration of the means of correcting those qualities which are most faulty. It would be tedious and out of place on this occasion, were I prepared with the requisite information, to enter into minute details on this important practical subject. It may suffice, if I venture to offer some general remarks and suggestions. As in considering the qualities of soils, so in attending to their defects, it may be well to observe the distinction between those which are physical, in contradistinction to those which are chemical. As regards the first, the main defects of faulty soils are, considered in the greatest degree of generality, of two different and opposite kinds — excess of tenacity or stiffness, and want of adhesion (and this in excess) or looseness; the one defect most conspicuous in the most perfect clay soils; the other in the most perfect sandy soils —the one depending on the argillaceous element being too predominant; the other, on the absence of this element in its plastic state, and on the predominance of sand, or of particles compact and firm, without tendency to cohere, which constitute what we commonly call sand. In one or other of these two kinds of defects, I believe are comprehended all the imperfections of your soils phy-

sically viewed, and that they are to be corrected by attending to them as principles.

If a soil is too adhesive, too stiff, presenting during a period of drought a hard fissured surface, during wet weather a state of bog, how is it to be treated for the removal of these great and fatal defects in the way of successful agriculture? Is it not best done by the addition of matter of a different kind, such as sand, chalk comminuted, marl, or burnt clay? Either of these will tend to diminish the stiffness, render the soil less adhesive, more pervious to air and water; especially, if followed by thorough draining and subsoil ploughing, which will aid most materially in preventing the stagnation of water, and, I may add, of air in the upper stratum of soil, and conduce in a remarkable manner to preserve the soil of a just degree of humidity and of aëration, even in times of severest trial — those of flood and drought. Such measures of improvement are necessarily expensive, and demand for their correct performance a large outlay of capital. In England and Scotland these measures have had a most extensive trial, and as you are no doubt aware, with most successful results, proving that capital so invested is most profitably placed, often doubling and tripling the value of the land in relation to produce and rent, and that not for a short term of years, but for an indefinite period;

in brief, land so treated and improved may be considered as reclaimed land, a great acquisition to the proprietor, a great acquisition to the country, an element I may say of wealth, and even of health; for it is clearly proved that by thorough draining even the climate of a district may be improved, the air rendered drier, less liable to fog, even warmer in a cold country, and also free from malaria. In this island how many situations there are, and not inconsiderable tracts, which might be benefited more or less by such treatment. Wherever water rests long after heavy rain, there we may be sure the defect in question is present, existing either in the soil or subsoil, and admits of correction. And, I think, it cannot be doubted, that improvements which have been found of such vast importance in England, so lucrative and advantageous to all concerned, would not be less so in Barbados. We know of one gentleman, to whose writings tropical agriculture is under no small obligations, who has commenced thorough draining on a part of his property in this island, which, from its qualities, he was of opinion required it. As the process was begun only a few months ago, and is not yet completed, it is too soon to witness any remarkable effect from it; and yet, some effect, I understand, is already apparent; a gentleman, a very competent judge, who was lately at Lambert's, has

told me that the canes over the drains were green in their stalks and growing, unaffected by the dry weather at that time prevailing, whilst those not so situated had the scorched appearance connected with the suspension of healthy active vegetation, owing to want of moisture.

If a soil is too loose (to pass to the other extreme) from excess of sand and deficiency of clay, unretentive of moisture, rain water passing through it almost unobstructed, fatally parched in dry seasons, and never productive excepting in moist ones, what is the corrective to be applied? Is it not obviously an addition of that adhesive plastic element — clay, which is deficient? Respecting this, there can be no doubt. But a doubt may arise in the mind of the proprietor, whether the improvement calculated on may be worth the expense that must be incurred. The determination, the solving of the doubt, must of course rest on a variety of circumstances chiefly local, all connected with economical views,—as the probable quantity of clay required, the distance from which it is to be brought, &c., circumstances I need not dwell on or particularise.

Of the other order of defects, those depending upon the chemical composition of soils, I can speak with less confidence; for the subject is a difficult one, partly owing to its nature, and partly to the little attention it has yet received, espe-

cially in the West Indies. If we are to start from principles, certain questions must be asked and answered to enable us to make a successful beginning; such as, what is the exact composition of soil best adapted to any particular crop—for example, the sugar cane? If this can be determined, then we should have a principle to guide us; we should be no longer groping as it were in the dark: then the object of the planter would be to approximate as much as possible all his soils to the high standard soil; but which he can only do, by knowing their composition, what elements are in excess or in deficiency, or altogether wanting, compared with the standard. At present, I fear the state of tropical agriculture is not sufficiently advanced to enable us to say what this standard soil is, how it is constituted; and it may be long before the problem will be solved; and certainly, never without the aid of scientific research and the joint operation of the man of science and of the practical agriculturist—or, what would be best, the union of the two — one who would be capable of testing and analysing soils, with opportunities of comparing their produce with their composition, and of instituting experiments on soils artificially compounded, in further proof of the accuracy of his deductions. Such trials, allow me to observe, are well worthy of attention and of encouragement from this and the

other agricultural societies of Barbados; and I trust there is a gentleman holding an elevated grade in one of those societies, who, as I believe he is competent to the inquiry, will be disposed to engage in it, and will find leisure for it, during intervals that he is not performing the high function to which he has recently been called in your House of Assembly.* After what I have said, I need hardly remark that at present it appears to me that conjectures only can be offered on the composition of the soil best fitted for the perfection of the sugar cane. From the limited observations I have yet had an opportunity of making, I am disposed to offer it as my opinion that soils principally calcareous are the soils in question, such as the chalky and marly. These soils, as regards physical condition, possess all the properties most desirable in a soil. And, as regards chemical composition, they may be held to be nowise defective when they contain, besides carbonate of lime and a portion of alumine, some magnesia and silica, with the phosphate of lime, and the vegetable alkali, as is commonly the case in the instances of the chalk and marl of this island, — most of them inorganic elements, found in the ashes of the cane, and that very generally. I have already adduced an example of what appears to

* Dr. Goding, then Speaker of the House of Assembly.

be the admirable fitness of a chalky soil for cane cultivation. I did not specify the exact locality where the cane grows so well without manure, — which I ought to have done, to escape, perhaps, the censure of hasty generalisation. The spot so pointed out to me was in a part of Welchman's Hall Estate, situated below the limitary coral cliff. Other examples might be mentioned of soils of the same kind being eminently productive. Is not the lower portion of the Codrington College estate such an instance, where the soil is an argillaceous calcareous marl, with a sufficiency of silica, and some phosphate of lime? In Antigua there are striking examples of it: the most valuable estates of that island have a soil of calcareous marl, with a subsoil of the same—a marl similar in composition to the best in Barbados. And such lands, I was informed on the spot, commonly yield three hogsheads of sugar per acre, occasionally, and not unfrequently, more; they require little manure, and are as fertile now as when they were first brought into cultivation, some of them more than a century ago.

It is true, moreover, and deserving of all consideration, that there are other kinds of soils, both in Barbados and in Antigua, which I am informed yield sugar superior to the average, and in fair, although not in large, proportional quantity. In these, as far as I have had an opportunity of judging, the same elements exist

as in the calcareous soils, although in widely different proportions; lime and magnesia in small quantity, and the phosphate of lime rather in the manure than in the soil. This is a fact which suggests another train of inquiry in connection with the first, viz. what are the proportions in which certain inorganic elements, when required, should be introduced into a soil, with a view to economy and the greatest profit?

As regards the improvements of the soils of Barbados, whether in relation to physical condition or chemical composition, many of the circumstances of your estates are highly favourable, and may, I think, in truthfulness, be adduced as matter of congratulation. Sea-sand, composed chiefly of comminuted shell, containing, besides carbonate of lime, a little phosphate of lime, and animal matter, such as is the composition of this sand on two thirds of the shores of this island; marl, containing the majority of the inorganic elements of the sugar cane, of such common occurrence that hardly an estate in the larger portion of Barbados is without its marl pit; chalk, which in chemical composition is very little different from marl, and might be superior to it were it reduced to powder, in certain situations existing in vast quantities: these are some of the happy means with which, I may say, Nature has provided you, capable of effecting, I believe, most of the improvements

required in the constitution of the more tenacious and too argillaceous soils, which are the most important and extensive, and with a probability at the same time of having their composition improved. And, then, for the lighter and too sandy soils, of which I believe the proportion is small, the abundance of clay at hand in most situations affords ready and ample means of amelioration. Of the good effect of such an addition on a small scale, a striking example offers at the Crane, a spot in many respects remarkable; where we witness an apparent retiring of the sea, owing to a vast accumulation of sand on the shore; and there, in this sand, below the cliff, where once the waves broke, of which the effects are manifest in the manner the base of the cliff is worn away,— fruit trees are now flourishing, a garden has been formed; and all that has been found necessary in the planting of the trees has been to introduce about their roots a little ordinary soil; the cocoanut, when deposited, not even requiring this. And not only do most fruit trees flourish there — such as the orange, the lime, the bread-fruit tree, &c. — but even the sugar cane! I was informed by the proprietor, that it is difficult to get it to grow, but that when it passes its early stage its growth is of extreme luxuriancy.

Such means as those I have mentioned — such facilities for the improvement of your soils — are

unquestionably great advantages, and, with the qualities of your soils generally, as I have already said, a subject for congratulation; and they are advantages which will be even increased when rendered more available, as it is to be hoped they soon will be, by railway communication encircling the whole, or at least the greater part, of the island. This is an undertaking which, if properly conducted, cannot fail of success. And with its success, depending on judicious and intelligent exertion and enterprise, may it not be anticipated that other exertions will be made in the same spirit, conducive directly or indirectly to the improvement of agriculture, and to an increase of prosperity? For, allow me to ask, what branch of it, or of the manufacturing processes connected with it, whether the making of sugar or of rum, can be considered perfect, or even a near approach to perfection?

Regarding the present time, which is called, and perhaps justly, a critical time, I would observe, that *this* is remarkable in the history of mankind — to wit: that periods of difficulty have always preceded, or have always accompanied, those of improvement and advance; and, I apprehend, for the simple reason, that it is commonly only by difficulties that the mind is roused to exertion, and that no great change or advance can be made without exertion

of mind. The West Indies, I am very sanguine, with this island taking the lead, will afford another example of such success, in a flourishing and prosperous future, the result and reward of such exertion. And a bright and most encouraging example it will be, taking a view of slave and free labour, viz. that what is right morally, is right—that is, advantageous—politically. And let this be proved—and I am very confident it will be proved here—not that free labour, considered by itself, is cheaper than slave labour, but that the system of free labour, the system of freedom, of that system which calls into action the energies of man, is more productive, is more profitable, than the opposite degrading and torpifying system of slavery. Let this be clearly proved within the tropics, as it has already been proved so triumphantly at home, comparing the past condition of our country with its present; comparing free England with other countries of Europe, hardly yet free, that have not yet constitutions (a most significant term),—will not the argument be almost irresistible against slavery and slave labour? My own belief is that it will be so, and that the monstrous evils of slavery (monstrous, either in act or tendency) will, ere long, be entirely got rid of: an aspiration, I am confident, which, if not received with the same strong faith in its completion, will be met with as

strong a feeling by all here assembled in favour of it, and, perhaps, even with a feeling stronger and more lively than I can have, many of you having witnessed the blessings of the change from the one system to the other, and being thankful for it, even with the impression of having sustained hitherto a pecuniary loss, a diminished annual income, but for which you have been more than repaid by the various benefits, moral and social, the results of emancipation.

Gentlemen, I must now hasten to conclude. There are many points of inquiry connected with your soils that I have not even touched on, and those of no little importance: such as the effect of burning where there is an apparent excess of vegetable matter, as in the black soils of Barbados; the state and proportion of the vegetable matter in your soils generally; the question of the exhausting powers of different crops, and the state of the soil in such lands as have been under cultivation uninterruptedly for a long series of years; the effects of irrigation as a fertilising means; the peculiar effects of different kinds of manures; besides other and hardly less interesting topics. Having occupied so much of your time, I can merely allude to these at present; perhaps, at some other meeting, should it be your wish, I may undertake the consideration of one or more of them, provided my official duties allow me

leisure, and I shall have it in my power to collect in the interim information such as will enable me to bring them before you with some chance of being useful, and especially in the way of opening and exciting inquiry (a word, in regard to the attainment of knowledge, of admirable import), without which, systematically conducted, we have no right to expect any great improvement in agriculture, whether considered as an art or a science; or, indeed, in any other departments of the arts or sciences.

DISCOURSE III.

ON MANURES, AND THE PRINCIPLES OF THEIR ACTION.

Gentlemen, — In the discourse I am about to have the honour to address to you, it is my intention to bring under your notice the subject of Manures. To you, as practical agriculturists, I need not insist on, or endeavour to point out, its importance. One word may suffice to convey an idea of it, and even an adequate idea, viz. that manures are the *food* of plants. And this definition suggests the analogy that exists between plants and animals; which I shall dwell on for a moment, and revert to, because I believe it to be instructive, or fitted to bring clearly to the mind some general views which may be an aid in discussing the subject, considered scientifically; that is, as regards principles or general rules deduced from facts or experience, and themselves applicable to practice.

Plants and animals have in common the distinctive property of reproduction, a power exercised by means either of a bud, slip, seed, or ovum,

the seed of one being analogous to the ovum of the other; whilst the bud or slip manner of generation are common to both, and constitute one of their most remarkable links. Having a common mode of origin, so they have of growth: as the animal grows, not like the mineral from accretion from without, but by deposition from within, so likewise does the plant. Both plants and animals are nourished by, and owe their growth to, foreign matter introduced from without; and both cease to grow, both waste, and ultimately perish, if the foreign matter constituting their food be withdrawn. To both, warmth, light, air, and moisture are, in certain degrees, essential to their well-being; and to both, in other degrees, these are injurious. Whilst there are thus certain resemblances between plants and animals, there are also marked and characteristic differences. The two most remarkable are intimately connected with the subject under consideration—the kind of food required by each, and the kind of organs belonging to each for its reception. A mouth and stomach appear to be essential to the animal, in which the food taken is prepared, more or less, for distribution and nourishment. In the plant, the preparation appears to be external, viz. in the soil, from whence the nutritive fluid is absorbed by the delicate roots, and by them conveyed for distribution where required. As to food, animals

are dependent for their support on one another, or on vegetables. Plants, on the contrary, are not so dependent; they derive their support from the soil and from the atmosphere: and whilst animals, in the act of supporting themselves, convert organic into inorganic matter, vegetables in their growth have the opposite effect — they create or form organic from inorganic materials; are, in brief, organisers for the sustentation of animal life. Let us take an example: — A single seed of Guinea corn (*Sorghum vulgare*), weighing about a quarter of a grain, planted in an artificial soil composed of several earths, and containing a little phosphate of lime, and salts of the vegetable and volatile alkali, under favourable circumstances, with sufficiency of moisture from rain, will rapidly vegetate, give rise to a plant many feet in height, and in less than six months yield a ripe head of corn, weighing, in its dry state, 1685 grains, and containing 3537 grains of seed; for such I have found to be the weight of a head of average size, and such the number of the seed it contained: the weight of the seed alone was 1460 grains. What a vast increase is here! And if we examine the parts of the plant, its roots, its stem, its leaves, its seed, we shall find them composed of substances differing altogether from the materials which had constituted the food of the plant; a difference depending on a new combination of

elements, — on a change, in brief, from inorganic to organic compounds.

There is another point of difference, and a very interesting one, between plants and animals—the effect they have on the atmosphere, comparing the leaves of the one with the lungs of the other. Animals inhale common air, consisting of azote and oxygen; a portion of the latter disappears, and its place is supplied by carbonic acid, which is a compound of carbon and oxygen, and which is expired; and consequently, in respiration, animals are consumers of carbon, and its consumption is attended with the production of animal heat. Vegetables, on the contrary, absorb or take in carbonic acid, and exhale oxygen, by their leaves, and, consequently, are accumulators of carbon, and, it may be, have the effect, in evolving oxygen, of occasioning a reduction of temperature, or of creating a cooling process, the opposite of that of the animal heating process. Should this be proved to be the case, it will be another example of wise and most happy adaptation.

I have spoken of vegetables as organisers, or the producers of organic compounds for the support of animal life: taking another view, animals may be considered as performing a part as essential to vegetable life, that of disorganisers; what is excrementitious from them being so reduced as to have the character rather of inorganic than of

organic compounds; whether it be carbonic acid, with which they contaminate the air in respiration, —their gaseous excrement,— or their liquid and consistent, derived from the other excreting organs and passages of the body. These matters, which are destructive to animals, and not only to the animals that void them but to animals generally, may be held to be the highest kind and most appropriate food of plants. And the more we reflect on this, the more we are convinced of its truth, the more we must admire the connection and mutual dependence. The animal enriching the air for the use of the plant, the plant purifying the air for the use of the animal, and the same in regard to the soil, offer a lesson to man of a very instructive kind, most beneficial when carried practically into effect, most injurious when neglected: in the one instance insuring fertility and, I may add, salubrity; in the other, the production of sterility and disease.

Let us now, for a moment, take a glance at the composition of plants and animals. Both may be considered as composed of nearly the same elements, few in number, but variously united, so as to give rise to very many different compounds. The principal constituent elements of both are carbon, hydrogen, and azote, oxygen, lime, potash, silica, and phosphorus. Of these, carbon and silica preponderate in plants (silica, indeed,

strictly is confined to plants); azote and phosphorus preponderate in animals. In plants, a large proportion of carbon and silica are expended in forming the woody fibre, the framework of the vegetable structure, and the epidermis, the resisting outer covering; whilst in animals, the azote and phosphorus are as largely expended in producing the organs of locomotion, the muscles and bones. And in each instance we witness the usual happy economy of nature, and fitness of means to an end. Plants, being fixed to the soil, take from it that which is almost always abundant in a fertile soil,—silica, a substance, even in a thin and delicate layer, imparting great power of resistance, and far less soluble when acted on by rain than the less common, or at least less abundant, phosphate of lime. Animals, on the contrary, being able to range abroad in quest of food, select such kinds as contain phosphate of lime and azote, and these kinds such as admit of digestion and assimilation, and of conversion into bone, muscle, &c.; following, in so doing, their natural tastes, undoubtedly instinctively directed.

Leaving these general views, it may be well to consider the subject we have entered upon somewhat in its details.

Physiologists who have directed their attention specially to the food of animals have arrived at the conclusion, that, amidst the extraordinary

variety of articles capable of supporting animal life, there are three which may be considered as of most importance, and, as it were, elementary alimentary substances — substances which are found in milk, viz., an albuminous matter, the curd; an oily matter, the cream; a saccharine matter, the sugar of milk. It seems to be proved, by a wide induction of facts, that articles containing these substances, or their analogues, such as starch for sugar, muscle for curd, any kind of fat for cream, are fit for the food of animals generally, and that no articles are fit that do not contain more or less of these. These substances, taken into the stomach, are converted into a pultaceous semi-fluid chyme; from whence a milk-like chyle is formed; and from whence blood, by which every part of the body is nourished in its constant circulation.

The results of the inquiries of physiologists as regards the food of vegetables have not been so well defined and satisfactory. As the sap of plants is a fluid, and transparent, we are sure that complete solution is essential as a preliminary, and that nothing enters the spongioles of the roots organic in its structure, a state of perfect solution being incompatible with such structure. The principal part of the sap is water; in it are dissolved carbonic acid, phosphate of lime, carbonate of lime, carbonate of potash, and, in very

many instances, silica. And these inorganic substances, I apprehend, are to the plant for its food what the organic substances before mentioned are to the animal for the same purpose; and these are not less elementary than those as nutritive principles. The sap so impregnated, passes from the rootlets by ascending vessels to the leaves, undergoing some change in its passage, but a greater change in the leaves, where carbonic acid is decomposed under the influence of light, oxygen evolved, and woody fibre either formed completely, or a substance formed about to become woody fibre, and to be deposited by the sap in its descent through another order of vessels. And as in the animal frame very different compounds are secreted by different glands, so, too, in the vegetable a vast variety of compounds are produced by an analogous function of secretion; tubes and cells in the latter corresponding to glands in the former, the ultimate structure of which is also similar, the glands being congeries of tubes or cells.

Returning to the sap, it may be asked—and it is an important question—How are certain of the substances, which I have mentioned as essential to this nutritive fluid, dissolved in the water of the sap; such as phosphate of lime, carbonate of lime, silica, themselves insoluble in water? My belief is, and it is founded upon experiments

which I have made, that their solution is effected by the carbonic acid in the sap. It is well known how soluble carbonate of lime, and I may add carbonate of magnesia, is in water containing carbonic acid; it is quite certain that phosphate of lime is also soluble in the same, and that not in an inconsiderable degree; and the experiments which I have made on silica to me are convincing that it likewise is soluble in water impregnated with carbonic acid, though in a degree very much less than phosphate of lime.

Taking this for granted, a certain simplicity is imparted to the theory of the nutritive process of plants. A fluid medium, water, holding a gaseous acid, carbonic acid, is the menstruum of the inorganic substances derived from the soil which the plant requires for its healthy growth. This compound solution becomes exposed in the leaves to the action of light, and to the evaporating agency of the winds; the carbonic acid undergoes decomposition as already mentioned, carbon being detained for the use of the plant, oxygen being exhaled; a portion of the water is removed by evaporation, and, in consequence, the solvent power of the menstruum is diminished, and depositions of silica and carbonate of lime and other ingredients take place. This view, it appears to me, is not only recommended by its simplicity, but also by a certain beauty and exactness of adjustment and

economy of means. Is it not very admirable that a gaseous acid, which with water, is to yield to the plant, by decomposition, its organic elements, should be the solvent and vehicle of its inorganic parts?

Limited as I am in the delivery of this discourse by time, my main object has been to give general views, precise in themselves, and I believe correct, and involving principles capable of being carried out into practice, the test and confirmation of scientific truths.

On the practical part of the subject of manures, it is not my intention to enter at any length. I have neither time for it, nor the experience requisite to do it justice, or to treat of it in the manner I could wish. In the further observations which I propose to make, I shall restrict myself to such remarks as I hope may be suggestive, may excite curiosity and inquiry, and so have a chance of being useful; intelligent inquiry being, as I think, the one thing, perhaps, the most needful, without which agriculture can never steadily advance, and under which it cannot fail to advance, and from an art, which it is at present, and obscure in many of its parts, become a science as certain in its results as is compatible with the uncertainty of the weather, and of other circumstances not under the controlling power of man.

What are the principal sources of manures or

of fertilising means? I shall briefly speak of them under a few heads: — 1st, of the atmospheric, chiefly in the form of rain; 2dly, of animal matter; 3dly, of vegetable matter; and, lastly, of mineral.

1st, *Of the fertilising means derived from the atmosphere.* — The atmosphere, as you are aware, is a mixture of two gases, azote and oxygen, in certain, almost constant proportions, and of carbonic acid and aqueous vapour; the former in small quantity, little variable, the latter in a variable quantity, and extremely variable, according to circumstances of temperature and other influences on which its increase and diminution depend. And besides these ingredients, there is reason to infer that various other substances are either suspended, floating as minute particles — organic and inorganic, — dust of several kinds, or dissolved in the air, such as carbonate of ammonia, common salt, and some other salts derived from the sea. The most important of all these atmospheric ingredients are, undoubtedly, the oxygen, azote, carbonic acid, aqueous vapour, and ammoniacal salt. I should exceed my limits as to time were I to enter into particulars on the fertilising agency of any one of these substances. Aqueous vapour condensed and precipitated, you know, occasions rain, — is in fact rain. When it falls, it brings down with it carbonic acid, some oxygen, and

azote, and there is reason to believe, a minute portion of carbonate of ammonia, all dissolved in it. Rain moistening dead vegetable and animal matter at the surface of the earth, favours their decomposition, and the evolution of carbonic acid and of carbonate of ammonia; penetrating beneath the surface, descending into the soil, it has a like effect there; and there becoming impregnated by means of its solvent power with what is found in a fertile soil, the substances already alluded to, as phosphate of lime, carbonate of lime and magnesia, carbonate of potash, and silica, it passes into the growing plant, absorbed by its roots, and becomes its nutritive sap. Thus complicated is rain in its agency; so various are the circumstances which concur to this agency; and so happily are they connected, one favouring the action of the other, and all promoting the process of vegetation. Reflecting on these circumstances, we cease to wonder at the growth of forests in a state of nature, in which for a long series of years vegetable matter, living or dead, is constantly accumulating, deriving its elements solely from the atmosphere and the soil; and by what it abstracts from the former greatly enriching the latter.

2dly, *Of the fertilising means derived from animal matter.*—I have already alluded to the composition of animal matter, and how, as regards its ultimate elements, excepting that it contains

no silica, it differs, compared with those of vegetables, rather in proportion than kind. Readily putrifying under the influence of oxygen and moisture; readily giving up its elements in the form of carbonic acid, carbonate of ammonia, phosphate of lime, it is easy to conceive how it may promote vegetable growth, and especially the growth of those plants, into the composition of which much azote and phosphate of lime enter, as in the instance of all the corn-bearing grasses and all the leguminous plants, and, in brief, all those which are highly nourishing as the food of animals. When I speak of animal matter, I speak of it almost without exception; every part of an animal (excepting, indeed, fat, a substance which contains no azote or phosphate of lime,) being adapted by its composition to have a fertilising effect, whether bone, or hair, skin, or muscle, whether blood or urine. This general fitness of animal matter for the purposes of manure is most deserving of being kept in mind, associated with the fact that the animal matter does not act, except when undergoing decomposition; that is, it is not the blood that fertilises applied to the soil, but the elements of the blood, and so of the urine and other excreta. I beg to call your attention to this, because it appears to me that economy is not observed in the West Indies in the use of animal manures. Large quantities of

guano are imported at a great cost, and applied to your cane-fields, whilst the bones of all the cattle that are killed for the market, or die of disease, are neglected. I speak of guano and bones thus together, because guano contains a large proportion of the same ingredients as bone, viz. phosphate of lime, and so far they are adapted to act the same part. Besides phosphate of lime, guano contains ammoniacal salts. It is a matter, as you are no doubt aware, derived from the excreta of sea fowl, their urine and dung, partially decomposed. Its nature should be remembered; it should be remembered that the excreta of other animals are hardly less valuable, and without exception; and, as before observed, these are the matters rejected by animals, and noxious to them, which seem by nature specially intended to be the food of plants. Though it little attracts common attention, there is not an animal in its wild state that does not promote vegetable life; the urinary secretion of the smallest insect differs but little from that of the sea fowl, the source of guano, and, in consequence, even when insects are destructive, they may fertilise, so that sometimes it may be a problem whether the good effected by them in one way may not preponderate over the evil they occasion in the other. But it is not my wish to appear paradoxical; I mention these circumstances because I believe

them to be deserving of attention, and fit to illustrate the nature of animal manures.

3dly, *Of the fertilising means derived from vegetable matter.* — That vegetable matter should be fit to be the food of plants is most easy to be conceived *à priori*, and that it is fit, is proved by the most extensive experience, and this generally, and without exception, in different degrees, as in the instance of animal matter; and also as in the instance of animal matter when undergoing decomposition; that is, when under the influence of moisture and atmospheric air, the vegetable matter is becoming resolved into the compounds from whence it originated. It is a happy circumstance for agriculture that vegetable matter, in a dry state, undergoes little or no change on the surface of the soil; it also is a happy circumstance that it undergoes little or no change under the soil, even when moist, if atmospheric air be excluded. Moisture and atmospheric air are essential to the growth of plants, and being essential also to the decomposition of vegetable matter, the latter takes place when it can be useful to the former. One of the peculiarities of cane-cultivation in Barbados, and, I apprehend, a very judicious one, is the strewing of the leaves of the last crop on the surface of the cane-field, to protect the young plants from the sun's rays and from parching winds. Conjoined with this effect is another which takes

place, though, I believe, not contemplated, viz. that of manuring the young canes. So long as drought prevails the old leaves are protectors, themselves unchanged; so soon as the rains set in, even if there be only a single shower, their decomposition commences, and their fertilising influence is exerted.

An idea commonly prevails, that soils by long culture are worn out and exhausted. Under one system of cultivation this may be, as when the crops, the produce of the soil, are in no part returned to it; but it cannot be in ordinary course if the reverse practice be observed, the tendency of vegetation being to enrich the soil: in brief, the great fertility of what are called virgin soils appears to be owing, not to a state that the word implies, but to the plants which have grown on such a soil having undergone decay there, and by their decay manured and enriched the soil. Take the example of a native forest: the trees composing it spread their roots in all directions and to a considerable depth, from whence they collect the inorganic materials requisite; these are conveyed into the leaves and into the wood of the trunk and branches, in which also carbon derived from the atmosphere is stored; the leaves fall and decay, and in time the trees, and decompose, and in decomposing give carbonaceous matter to the soil, and restore the inorganic materials extracted,

and, as it were, collected and concentrated. Such is the natural tendency of vegetation, and such, also, is the effect of judicious management when green crops are ploughed in as manure, or when the greater part of the ripe crop is returned to the soil, whether directly, as in the instance of the application mentioned, of the leaves of the cane to the surface of the soil, or indirectly in the state of stable-dung or pen-manure, the vegetable matter having been first used as forage. This view is simple and clear, resting on the principle that vegetable growth and the enrichment of the soil are concomitant; and I believe that, generally, it is a principle of practical application. There are, however, facts deserving of attention and of careful study, which prove that the growing of plants of the same kind for a series of years, the plants decaying where they grew, has an injurious effect on the soil, as regards its power of supporting these plants, indicated by their disappearing, followed by other species which grow luxuriantly, proving unexhausted fertility; that is, that the soil has been so modified by one species as to be rendered unfavourable to it, and yet favourable to another species. Now, what is witnessed in a striking manner as the result of a long series of years in soils under forest growth, may take place, though not in a marked manner, from year to year in

artificial culture. Moreover, the reverse of the preceding, one plant, though not carried off the soil, may be injurious in preparation for a crop even of another plant. I make this remark, keeping in mind a fact which was mentioned to me by a gentleman of Barbados, one of its ablest practical agriculturists; it was, that on some estates in this island, the growing of guinea corn and the ploughing or turning it into the soil in its green state, had a decidedly injurious effect. This partial effect, and the effect before alluded to, are problems which are yet unsolved, doubtlessly admitting of solution, but of solution which can only be attained by scientific inquiry. In the instance first mentioned, the soil beyond a certain depth may be exhausted of the inorganic matter required by the plant, and which may be accumulated at the surface in a state unfavourable to the exhausting species, and yet favourable to another species. In the last mentioned instance, the guinea corn may so unite the inorganic elements which it extracts and returns to the soil, make such compounds of them as to be unfavourable either to their solution and entering in to the sap, or if soluble, to their affording supporting nourishment to the cane. These are mere conjectures, but whether true or false, can be determined only by exact research.

Lastly, *Of the fertilising Means derived from*

Mineral or Inorganic Matter. — The most fertile soils appear to be those which are most compounded, which contain the largest number of the inorganic elements of plants, and in a state of minute division favouring their solution to enter into the composition of the nutritive sap. Lime, magnesia, silica, potash, phosphate of lime, may be mentioned as the most important of these; and these may exist in the soil in different states, either as free, uncombined, or in combination, constituting mineral species. If the former, they are more readily yielded up to the growing plants, and the soil, without care, is in danger of being sooner exhausted: if the latter, they are yielded up more slowly, as the minerals decompose, and in consequence, exhaustion, even with bad management, is difficult. Such fertilising means as these in the soil, depending on its supplying the inorganic elements of plants, are obvious. There is another source of fertility in the soil of a more obscure kind. There are some soils, for example, capable of yielding nitre, and that for successive years. Nitre, you know, is a compound of nitric acid and potash. When formed in a soil, there is reason to infer that invariably the alkali is furnished by the soil, derived from a compound mineral, and that the elements of the acid, azote and oxygen, are furnished by the atmosphere, and that in consequence of certain ingredients in

the soil favouring the union of these elements, especially lime, the acid is formed and the salt is produced. So there are other conditions of soil in which clay, and perhaps oxide of iron, act a part, promoting the production from its elements, viz. azote and hydrogen, of ammonia, or the volatile alkali. And as the substances first mentioned, lime, magnesia, potash, silica, are fertilisers as inorganic elements, these latter, nitre and the volatile alkali, are probably useful in administering to the formation of the organic parts.

In taking a view of the capabilities of a soil, let me add, that the attention should be given to the under portion, to the subsoil, as well as the surface soil. If the latter be neglected and never turned up and brought into use, great may be the loss to the agriculturist. Water holding carbonic acid in solution, I have endeavoured to show, is the principal agent or menstruum by which the sap is formed and plants are fed. This is the result when it is absorbed by the roots, and is transmitted by their ascending to be distributed to the various parts where required; but when, instead of being thus absorbed, it passes from the soil to the subsoil, it impoverishes the former and enriches the latter, removing out of it more or less of the soluble constituents, so that you may have at the same time an exhausted surface soil and a rich subsoil, requiring only a

change of place, it may be, a mixing of the two, to become highly productive.

Gentlemen, I must now bring this discourse to a conclusion. As I began it with drawing your attention to the analogy between plants and animals, I do not know how I can better finish it than by reverting to that analogy. All I have hitherto said has been on the subject of manures generally, as involving common principles universally applicable. Not a less important part of the subject is that of special manures, or of the choice of manures for particular crops; and this is by far the most difficult part, and the one hitherto least studied. In animals, their coarser organisation is distinct. If we examine the teeth of any particular animal, its stomach, its intestines — the main organs concerned in its nourishment — we have no difficulty in deciding from their structure whether the individual is carnivorous or herbivorous, or fitted for and requiring a mixed diet of animal and vegetable food; and this, be it one of the mammalia, birds, or insects. But not so as regards plants; the organs concerned in their nourishment are so minute as to escape detection by the eye unaided by the microscope; and even when examined by this help, no differences characteristic have hitherto been detected, admitting of being associated with the quality of the nourishment best fitted for the individual plants.

This, then, (taking it for granted, and it seems to be proved by experience, that different kinds of plants do not for their coming to perfection require *one kind*, but *different kinds*, of manure,) must be determined by other means. How is this important object to be accomplished? I do not know how it can be well accomplished, except by enlightened experience and by chemical research. In the instances of the corn-bearing grasses, such experience, such inquiry, have been highly useful. These are crops which are exhausting to the soil, the grain being consumed at a distance; and the more exhausting when the straw also is removed from the farm. To correct the exhausting effect, one of two measures is adopted; either to allow the land to remain fallow for a certain period, during which, owing to the decomposition and disintegration of mineral particles in the soil, and the addition made to it from the atmosphere by the agency of the elements, and by rains and winds, and from the subsoil, by the penetrating roots of native grasses and other indigenous plants, the loss is made good of these inorganic materials carried away; or, in a more summary manner, by restoring in manure (aided by intervening green crops) the ingredients abstracted and lost in the grain and straw — in the former chiefly phosphate of lime and azote, in the latter chiefly silica. The summary or shorter way last mentioned is the im-

proved method, the result of scientific research; the tedious way first noticed is the result of mere experience unaided by such research, and is in many respects imperfect. The same remarks, I believe, are applicable to every kind of crop. Take the most important with which the interests of the West Indies are connected, the sugar-cane. For its most successful cultivation — that is, its most profitable as regards its produce and returns, supposing the fallow system to be put aside as least judicious — it needs to be determined what kind of manure is best fitted to bring the cane to its perfection of growth as a sugar-bearing plant, and with most economy, keeping in view the balance sheet of an estate. If the problem is entered upon by the agricultural chemist, as I apprehend it should be, he will have to consider what are the elements constituting sugar; they are oxygen, hydrogen, and carbon, elements derived from the atmosphere, either directly or indirectly. He will have to consider what are the elements or proximate principles of the saccharine juice, as extracted by pressure from the plant; these, besides sugar, are, I believe, chiefly starch, in minute quantity, and albuminous matter, or a matter containing azote, and capable of exciting the vinous fermentation, and one or more vegetable acids: he will have to consider what are the elements of the cellular structure of

the plant in which the saccharine juice is contained, and the composition of the other parts of the cane; these appear to be very much the same as the constituent elements of the stalk and leaves of the other grasses, viz. phosphate of lime, silica, lime, magnesia, and potash, with the common elements, carbon, oxygen, and hydrogen. Having given consideration to all these matters, he may offer suggestions for trial. As the cane contains little azotised matter, and pure sugar none, he may suggest that the manure most likely to be successful is one composed chiefly of vegetable matter, or one in which the proportion of animal matter is small. As the sugar and other exports, viz. rum and molasses, contain very little of any matter of a mineral kind derived from the soil, he will conclude that, with good management, a cane-crop is not exhausting; and that if the leaves and stalks are returned to the soil, the land, instead of being impoverished, may be actually enriched, inasmuch as there is given to the soil a vast accession of vegetable matter, the elements of which have been obtained from the atmosphere, and which in decomposing render up these elements to support the growing crop, being, as it were, to the young plant what the milk of the mother is to the young animal. I should add, that the inquiry of the agricultural chemist will by no means be complete, unless his attention also

be directed to the soil, and that not only once, but at intervals. If, on his first examination of it, he find a marked deficiency in it of phosphate of lime and of other inorganic substances which seem to be essential to the composition of the sugar-cane in its healthy state, he will suggest the use of guano as a manure, or of bone-dust, or of marl containing phosphate of lime, according to circumstances. If, after an interval of a few years, the land having yielded good crops, he examines the soil again, and now finds in it no marked deficiency of phosphate or carbonate of lime, or other supposed requisite inorganic ingredient, he will, I conceive, be warranted in suggesting the sparing the expensive manures, the guano and the bone-dust, and using only manure, chiefly vegetable, made on the estate.

Such, I fancy, is the line of inquiry, as regards particular manures, that is likely to be most useful, and the more useful, I cannot but think it will be, the more minutely, and carefully, and judiciously it is carried out — testing theoretical suggestions founded on chemical analysis by the results of practical experience — that is, by well conducted trials — and extending them from point to point, till satisfactory knowledge is arrived at; so that, being acquainted with the quality of the soil, the quality and quantity of the manure applied, the mode of tillage employed, the planter

may be able to calculate, *communibus annis*, what will be the quantity and quality of sugar, what the quantity and quality of the molasses, and what the quantity of rum that should be made on his estate.

The subject of manures is far too large a one for a single discourse; many parts of it I have treated of very slightly; some, I am sure, very imperfectly, and perhaps obscurely: your knowledge and intelligence will supply many deficiencies, and I am confident I may equally rely on your kindness for exercising them, recollecting (be pleased to do so) that my main object has not been so much to impart minute information, as to inculcate some general principles, and to endeavour to excite inquiry,—that methodical and scientific inquiry which leads to exact knowledge, and, when diligently carried out, to the perfecting of every art to which it is applied.

DISCOURSE IV.

ON DRAINAGE AND IRRIGATION, THEIR THEORY AND EFFECTS.

Gentlemen,—On this occasion I shall, with your permission, bring under your notice the important and nearly allied subjects of Draining and Irrigation; important, as conducive greatly to fertility; and nearly allied, the mean element in both being water, without which, soils of the very best quality, you know, are barren.

Limited as we are for time, were there not other reasons for it, I must, in the short discourse, which I have now the honour to address to you, restrict myself in a great measure to principles, and avoid the details of the operations, whether of Draining or Irrigation. Should I be so fortunate as to enunciate clearly the former, and to convince any individual present, doubtful of the efficacy of these processes, that draining, or thorough-drained land, is essential to agriculture—if it be the intent, as it should be the interest, of the agriculturist, to conduct it in the most improved manner; and that Irrigation, wherever

practicable, most amply repays by imparting a wonderfully increased fertility; should I be able to accomplish thus much, I shall not regret passing over the minutiæ of details, which are best studied and learnt in systematic works on the subject, that is, if practical means of instruction are not available, which are the best of all.

The kind of draining to which I have to call your attention is not the common surface draining, but the new and far more advantageous method of deep and thorough draining, a method by which the excess of rain is conveyed from the surface of the land into its substance, and even to the subsoil and beneath it; to be retained in moderate quantity favourable to tillage, favourable to vegetation, favourable to the disintegration and decomposition of the coarse parts of the soil and of the subsoil, and consequently to the improvement of the quality of the soil, and to the formation of new soil fit for tillage.

These effects, so admirable, can only be elucidated and brought clearly to the understanding by considering the principles of the operation; or, in other words, the qualities of the different substances concerned, as of the soil and subsoil and their elements, in conjunction with rain and atmospheric air, and their agencies.

A soil fit for cultivation is never formed of any single earth; it is more or less compounded, and

the greater in degree, generally, the better is its quality. In all good soils there is a certain proportion of clay, and commonly of sand, either siliceous or calcareous, or a mixture of the two. What is designated clay always consists of many ingredients, of which alumine and silica are the principal. In three specimens from fertile soils in Flanders, carefully analysed, besides alumine and silica, there were found present eighteen other substances, the most important of which were lime and magnesia, the alkalies, including ammonia, certain acids, as the phosphoric, sulphuric, and carbonic, and two or three kinds of vegetable matter.

The peculiar quality of clay is, that it is retentive of moisture; and of the most complete clay in its condensed state, using the term in contradistinction to a loose state, that it is an obstruction to flowing water,—a property of vast importance in the economy of nature, without which the earth would be in great measure destitute of springs, the ground arid and unfit for vegetation, giving rise to a universal desert-waste. This peculiar property is mainly dependent on one earth, viz. alumine; and on the circumstance that when separated, in consequence of the decomposition of the mineral compounds in which it exists, it is, as when obtained by precipitation, by the addition of an alkali to a salt of alumine in solution, in a state

of extraordinarily minute division, with the power of adhesion, particle to particle, and of becoming plastic from compression, — a power this of not less importance in the economy of soils, without which it is obvious the surface of the earth would be in the state of a moveable, drifting sand, such as we find where the binding element of clay is deficient, as in the instance of the most remarkable deserts. Of this state of minute division you may satisfy yourself most easily by a simple experiment, the precipitating of alumine from a solution of alum by ammonia, and examining it under the microscope. So minute are the particles of the precipitate, that even when using one of the highest powers of a good instrument, a glass, for instance, with a focal distance of one eighth of an inch, they are hardly distinguishable; indeed, I may say, they are not distinguishable individually, only when connected one with another. This state of minute division of the detached alumine is connected with, and may be dependent on, another property of this earth, its perfect insolubility in water, and in water impregnated with carbonic acid; and owing to this insolubility its inaptitude, when so detached, to form crystals.

To appreciate these peculiarities of alumine, let us consider for a moment the qualities of the other earths, which are the other chief ingredients of soils, viz. silica, lime, and magnesia.

Silica occurs in soils chiefly in the form of quartzose sand, derived from the disintegration of certain compound crystalline rocks, especially granite, of which rock it is an ingredient. It also occurs in smaller proportion, in a very finely divided state, when derived, it may be inferred, like alumine, from the decomposition of certain minerals containing it, such as felspar. In this state it is soluble either by means of carbonated alkali or carbonic acid alone, as I believe, or water alone, according to a distinguished Swedish chemist. Owing to this quality it is capable of entering into the composition of vegetable textures. When deposited from its solution, it is not in the manner of alumine, but either in minute adhering crystals, or uncrystallised in the form of a compact hard stony crust.

Lime exists in the soil most generally in the state of carbonate of lime; even if introduced in the caustic state, owing to its strong affinity for carbonic acid, it rapidly absorbs this gas from the atmosphere. The carbonate has a strong tendency to crystallise; it undergoes crystallisation in the act of its formation, when the lime is absorbing carbonic acid. If you precipitate lime from a solution of one of its salts in water by an alkaline carbonate, the carbonate of lime thus obtained will be in minute crystalline grains, minute according to our ordinary ideas of bulk, but coarse

indeed, if compared under the microscope with the precipitate of alumine. Nor has it the property of alumine, as you may satisfy yourselves by a very easy experiment, of retaining water or preventing its flow.

Magnesia, like lime, having a considerable affinity for carbonic acid, commonly exists in the soil in the state of carbonate. But it has not the same disposition to crystallise, and in consequence, perhaps, its particles are finer; at least, this may be inferred from the examination of the carbonate, artificially obtained by precipitation by a carbonated alkali, added to the solution of a magnesian salt. These, though finer than those of carbonate of lime procured in the same manner, are visible individually under the microscope, and are therefore very much larger than those of alumine. And tested by water, the carbonate of magnesia is found to retard, not entirely prevent, its flow and transmission.

The relative minuteness of the particles of these three earths is well shown by the time required by each to subside after suspension in water by agitation. It will be found that the carbonate of lime will descend and find its place of rest rapidly; the carbonate of magnesia in slower time; and the alumine by far the slowest. And hence the wide diffusion of this last mentioned earth, a happy circumstance in the economy of nature. Washed

out of the naked, disintegrating rocks by rain, with mineral particles of other kinds, not so minute but hardly less diffusible, they are carried by rivers into seas, and by tides and currents transported even into the ocean; there they subside and form beds, destined, it may be, to become fertile soils on islands, or even continents, should the rocky foundations on which they rest be elevated into the atmosphere, as this island has been, and so many others, covered with beds of clay and soil, which we are sure from their nature are of distant origin.

Another peculiarity of alumine requires notice, in connection with thorough draining, to wit, its power of contracting in drying. No earth absorbs so much water, whether chemically or hygroscopically; no one retains it so powerfully, or contracts so much in losing it. There are before you precipitates, dried, of alumine, of carbonate of lime, and of carbonate of magnesia. How great is the difference in their appearance! That of the alumine is fissured in every direction; that of the carbonate of magnesia exhibits only a very few fissures; whilst the carbonate of lime has a smooth unbroken surface, indicating no contraction.

The two peculiar properties of alumine adverted to, and which are also properties of clays, chiefly depending on the presence of alumine, viz. being impermeable to water when expanded by it, that

is, when containing a certain quantity without a free outlet such as a drain affords; and being liable to contract and become fissured, and so permeable, on losing water, such as is drawn off by a drain: these two properties may be considered fundamental ones in connection with thorough draining, — the first giving rise to the necessity for the operation, the second rendering it practicable. In the first instance, it must be supposed, or taken for granted, that the clay is not so compact or condensed by pressure as to allow no passage to water, even with a free outlet, which is a quality, as already remarked, of the purest clays.

For this (the deep and thorough mode of draining) to be most efficient, it should be followed by subsoil ploughing, which breaks up the clay to a certain depth, and renders it more pervious to water and the access of air, without bringing any of the subsoil to the surface. The effect of subsoil ploughing, it may be remarked, is well illustrated, by taking a piece of stiff clay and breaking it up, when it will be found to be readily permeable by water; and again, when the water has drained from it, compressing it as a plastic mass, when it will recover more or less its impermeability, according to its quality — that is, the proportion of finely divided aluminous matter it contains, and the proportion of sand.

As it appears that, in some instances, this pro-

cess of subsoil ploughing has been of little advantage, not repaying the cost, it may be prudent to try the effect of it on a small portion of the drained land, and to be guided by the result as to its extension; for example, the quality and quantity of produce on the portion subsoiled, compared with the quality and quantity of the crop on an equal portion merely drained.

Allow me now to turn your attention to the atmospheric air and to the rain water, for the admission and penetrating of which into the soil, without stagnation of the latter, thorough draining, as regards its function, may be considered in the first place as instituted.

Atmospheric air, we know, is composed of oxygen, and azote, and carbonic acid in almost constantly the same proportion, viz. twenty-one parts in volume of oxygen, seventy-nine of azote, and about the one half of a thousandth part of carbonic acid, with a very variable proportion of water diffused through it in the elastic state in the form of vapour, and when in the vesicular state, or in that of minute particles, in the form of clouds; and also an extremely small portion, there is reason to believe, of carbonate of ammonia, and of some other matters, chiefly saline, either held in solution in it or in suspension.

Rain, it is to be remembered, is never absolutely pure water; it is variously impregnated, and this

in consequence of two offices which it seems to have to perform (not to mention others); namely, the purifying of the atmosphere and the fertilising of the earth. Carbonic acid, oxygen, and azote are always contained in it, and the former in considerably larger proportion than in the atmosphere, oxygen being more soluble in water than azote. And besides these, there are other matters, such as carbonate of ammonia, and various substances which, exercising its purifying function, it brings down with it from the atmosphere, in which they were suspended or dissolved.

The rain entering the soil thus impregnated, not only immediately promotes active vegetation, but also has an ameliorating effect on the soil and the subsoil, fitting it for the purposes of vegetation. The water, impregnated with oxygen, promotes the decomposition of animal and vegetable matter, thus forming food for plants; and acting on compound minerals in the soil and subsoil, it produces the separation of their elements, and thus forms new mould. Thorough draining, by preventing the stagnation of water and promoting its descent, administers in a remarkable manner to these ameliorating effects; and preserving the soil and subsoil in a porous condition, it administers also to another effect, not insignificant in the economy of vegetation — namely, the formation of ammonia by the union of the azote of the atmo-

spheric air penetrating into the earth with hydrogen, as it is disengaged from decomposing animal and vegetable matter; thus supplying an alkali, which appears to be the most active portion of many valuable manures, and is probably essential to the production, in plants, of all those albuminous substances, which are of the nature of animal matter, from which even animals themselves, those feeding on vegetables, are supposed to be formed, the vegetable being the generator and the animal only the recipient.

There are other good and important effects resulting from thorough draining, which I have scarcely time to mention, as its tending to counteract the evils of drought, as well as of excessive moisture, thereby favouring vegetation, and at the same time benefiting the climate, as it conduces equally to prevent either extreme—a parched state of the atmosphere, or excessive humidity and fog; and as it tends also to promote an equable temperature of atmosphere. In brief, it is difficult, I believe, to appreciate too highly the advantages of thorough draining to land that requires it. Mr. Smith, of Deanstone, who may be considered as the inventor of the process, has well said, that it requires *faith* to admit all the good it is capable of accomplishing, that good is so much beyond what the inexperienced in its efficacy would expect.

I consider it, I may remark, a circumstance of good fortune to have witnessed the results of the first trial made of it at Deanstone by this gentleman, and also the first attempt, I believe, of the kind made within the tropics—viz. in this island by your talented countryman, Dr. Phillips, on his estate of Lambert, and in Demerara by Dr. Shier, the able agricultural chemist of that colony, on an estate in the neighbourhood of George Town. At Deanstone, when I was there six years ago, the condition of the land and of the pastures was such as to excite admiration. Though the season was unusually dry, and fields adjoining the property were parched, in which rushes were growing, the Deanstone meadows, similarly situated, were beautifully green, and in them not a rush was to be seen or a weed. The harvest was over, but the farm-yard, in the numerous ricks of corn, bore ample proof of the great fertility of the arable land. The increased value of the estate, the result of its improvement from thorough draining and good farming, I am afraid to mention, lest I should lay myself open to the charge of exaggeration. Mr. Smith, who was my conductor and informant on the occasion, had a hole dug through the soil and subsoil to show the deepening of the soil from the decomposition and disintegration of the subjacent stony matter from the action on it of air and moisture. In Demerara, the result

of Dr. Shier's experiment, making allowance for the shortness of time, appears to be no less satisfactory. When I saw the field, in the latter end of May last (1847), after a heavy fall of rain, water was flowing abundantly from the mouths of the drains, whilst the surface soil was merely moist, and in a fit state for tillage; and having no open drains, such as are generally used in the colony, it was in a condition to admit of the plough and harrow, and the use of any other implement of husbandry likely to economise labour. In a letter with which I have been favoured by Dr. Shier, of the 3d of November, he makes mention of the thorough drained field as in a very prosperous state. Canes grown in it, cut when only six months old, gave a juice of the specific gravity 1,070; and an imperial gallon of this juice yielded 1 lb. 2 oz. of beautiful muscovado sugar, the molasses from which contained only about one third as much salt as molasses from other fields of the estate with open drains. For the success of the experiment at Lambert's, in this island, we have the authority of the Leeward Agricultural Society. In their report, dated the 2d of last May, it is stated that a field of two acres and a half, which in wet seasons had always failed, drained in April 1846, did not suffer at any period of the late wet season; "whilst the field adjoining, although of somewhat greater elevation, suffered materially

from the effects of water, making on an average one hogshead less per acre than the drained field, although manure had been applied to the former, and not to the latter." And I have had confirmation of these favourable results, and I am glad to say, on an extended scale, from the resident manager on the estate, Mr. Phillips. In a note with which he has obliged me, of the 1st of this month, he states that eight acres of land are now drained and planted, land similarly situated to that just mentioned, as, before draining, liable to suffer from heavy rain, the bad effect of which it has entirely escaped this year; and that the canes on it are very superior to any on the estate. He adds that there are now altogether fifteen acres drained, and that he hopes to complete twenty acres before the end of the year. He specially notices as worthy of remark, that during the severe drought some months ago, the canes on the drained land suffered least, and yet that the soil of this land, compared with any other, always appeared drier and more friable. All results, let me observe, in accordance with the principle of thorough draining, and the general experience we have of its effects.

I must not conclude the subject of draining, without briefly adverting to the qualities of the soil which may be considered as requiring, and to the contrary ones not needing it. If the soil be

sandy or abounding in marl, with a sandy or marly subsoil, it will be sufficiently porous to water; water will not collect and stagnate on it, except, indeed, its situation be low and almost on a level with the sea high-water mark. Moreover, if the soil be shallow, only three or four feet deep, resting on porous rock, such as the shell and coral limestone of Barbados commonly is, thorough draining would be superfluous, could it be effected.

Occasionally, however, and not unfrequently, this rock is covered with an adventitious incrustation of carbonate of lime, impervious equally to rainwater and the roots of plants. To give fertility to land so situated, this crust should be broken through, as I believe it sometimes is, preparatory to the planting of canes. In Malta, I may remark incidentally, where a like crust forms on the soft porous freestone on which the scanty soil of that island rests, from time to time the industrious natives bare the rock of its soil and make grooves in it, penetrating through the hard incrustation, so as to admit the passage of rain water into the rock, and its exhalation to the soil during the dry season.

The qualities of soil likely to be benefited by thorough draining are the stiff clay soils, or the lighter and more porous soils, with a substratum of such clays on which, after heavy rain, water rests in a state of stagnation.

Should it, as regards any soil, be a doubtful question whether it requires or not the process of thorough draining, a simple experiment may be made which may help to remove the doubt: it is by taking a portion of the soil, and subjecting it to the action of water in a tube, or a piece of bamboo covered at its lower end by linen, which will support the soil, and allow water to pass. If the soil, when compressed, acts in the manner of stiff clay, and does not allow the water to drop—to flow through it, it is a criterion of the propriety of draining, and the contrary if it permit the passage of water. Trials of this kind, I apprehend, may be advantageously made to test the properties of soils as to their retentive powers, which are graduated in a great measure by the proportion of alumine present and the proportion of the other earths in a finely divided state, any earth, if finely divided, tending to have the same effect as alumine in retarding or preventing the descent of water. The results of such trials, moreover, may indicate whether clay should be added to the soil to increase, or sand or lime to diminish, its power of retaining water.

I have spoken of Dr. Shier's experiment on thorough draining; let me add, what I should have done before, that you will find the particulars of it clearly detailed in his published report on thorough draining—a report most highly cre-

ditable to him as a scientific agricultural chemist, and as a scientific inquirer, and which, for the valuable and new information it contains on the subject of which it treats, is particularly deserving the attention of all tropical agriculturists who wish to enter into the minute details of the operation. It affords a happy example of science and practice combined.

I remarked, in commencing this discourse, that irrigation and thorough draining are allied: they are so, not only inasmuch as water is mainly concerned in both, but also as to the manner in which it is concerned. Thorough draining may be viewed as a slow and deep irrigation, the water descending from the surface to the drains or channels conveying away what is superfluous, whilst irrigation is the conducting of water over the surface of land in constant slow flow, so as to afford nourishment to the growing crop, which all experience proves it to do with wonderful effect. At the same time, it is to be kept in mind that the slowly flowing water does not act merely superficially, but that it penetrates deeply, and not only promotes vegetation, but likewise, when properly managed, has a tendency to enrich the soil, either by what it deposits, or by its action, through the oxygen which it contains, occasioning the decomposition of mineral compounds in the soil and subsoil, and the setting free of inorganic sub-

stances, those required for the purposes of vegetation, such as the fixed alkalies, lime and magnesia, and certain acids, especially the phosphoric, which plants, in the act of growing, are constantly abstracting from the soil, by—if uncompensated—an exhausting process. The penetrating water, impregnated with oxygen, is also beneficial in converting an injurious compound of iron, when present, the protoxide, into the inert and harmless peroxide, and likewise, and in a great degree, by favouring the decomposition of animal and vegetable matter, and the production of carbonic acid and ammonia. For these latter effects to be fully produced, the land should have the advantage of thorough draining.

Water of various qualities is employed in irrigation, and, as might be anticipated, with an effect varying with the quality, that depending on the substances suspended or dissolved in the water. The purer the water, the less it will differ in its effect from rain. The more of decomposing animal and vegetable matter it contains, the more the effect will be like that of rich manure, frequently applied, under the most favourable circumstances of season as to rain. The more of earthy matter it holds in suspension in a finely divided state, a state indeed necessary to suspension, the more its influence will resemble that of a well-watered virgin soil.

According to the kind of crop, water of irrigation, of one or the other of these qualities, appears to be preferable. The rice lands of the mountainous parts of Ceylon yield, year after year, excellent produce, irrigated by water differing but little from rain water. The vineyards of Zante and Cephalonia, the fruit of which is the currant grape, bear abundantly after a winter irrigation, the water used descending from the hills discoloured by clay, an argillaceous, calcareous marl, much resembling that deposited by the Nile — that vast irrigator and fertiliser of the ever productive valley of Egypt. The meadows in the neighbourhood of Edinburgh, irrigated by the strongly impregnated sewer water of that city, are well known for the enormous and repeated crops of grass they yield in the course of the year, almost without intermission.

The mode in which irrigation is performed is also various, depending very much on the scale. If for garden and limited field cultivation, in many countries the water used is raised from wells or cisterns by the Persian wheel, or by the lever and bucket, and distributed by little canals or gutters. If for extensive cultivation, streams are conducted from lakes or rivers, and their water admitted into prepared fields and diffused over them. There are works for this purpose in India — tanks and aqueducts of immense magnitude, miles in cir-

cumference and length, which excite the wonder of the passing traveller, and are, in the labour expended on them, little inferior to the pyramids of Egypt, themselves, it has been imagined, erected for hydraulic purposes. For every species of irrigation, I need hardly mention that there is one circumstance in common, which is, the making of the surface of the soil so gently inclined and regular as to admit the flow of water over or through it, uninterruptedly, with means of excluding the water when necessary.

Having stated thus much generally as to irrigation, I shall venture to make a few remarks on it in connection with the cultivation of the sugar cane, and the practicability of applying it far more generally than has hitherto been done to this, the staple crop of these colonies.

That irrigation is favourable to this crop, is, I believe, so well proved, that no doubt can be entertained respecting it. In this island, I understand, on one estate in St. Philip's, where the trial has been made, the success has been great, and that in periods of drought when, without irrigation, the canes would hardly have been worth the reaping. In Berbice, there are one or two estates that I heard of when there, which had always been productive, yielding, even in the dryest seasons, and always without the application of manure, not less than three hogsheads an acre, these estates having a command

of water brought to them by an inland never-failing stream, derived by a canal from one of the large rivers of that country.

This partial success considered, and the nature of the cane, it being almost an aquatic plant, is it not deserving of thought whether irrigation cannot be more generally applied, and whether all possible means, consistent with just economy, should not be taken to effect it, and even at intervals, and occasionally, if means permitting it only at intervals, be available?

In some parts of Barbados, especially in the parishes of St. Joseph and St. Andrew, and in that portion of St. John's below "the Cliff," there are running streams, some of them perennial, in a great measure running to waste, which I have no doubt might be turned to the purposes of irrigation with excellent effect, especially if connected with terrace cultivation, which, in certain of the hill sides in these parishes, where rock is in plenty, capable of affording stone for terrace walls of support, might be effected with no great labour, and probably at a small expense. Such terraces are likely to have the double advantage of facilitating irrigation, and of preventing the soil from being washed away by heavy rains. Not only in the parishes named, but in most parts of the island, I imagine, partial irrigation might be accomplished by forming channels in the cane

fields to receive, after any considerable fall of rain, the running water, in small streams, with such a declivity as to allow of their flowing slowly, remembering always that it is running water that promotes vegetation, and stagnant water only that injures it. Such small channels, after heavy rains, might also prove useful in preventing that accumulation of water which occasions a destructive flood, that designated here, from its effects, "a wash."

Were thorough draining introduced, the water in excess from a higher level, discharged by the drains, might be made applicable to partial irrigation in fields of a lower level. Such water, no doubt, would have a fertilising effect; and, perhaps, even more than ordinary rain water, as it would contain certain saline substances and other compounds which are soluble, derived from the soil, and it may be from the manure in the soil, whilst the water is in the act of passing through it, and thus partaking of the quality of spring water, which is always more or less impregnated with foreign matter from a like cause, spring water being rain water that has passed through the natural filters of the earth's surface. Could this water be so applied to irrigation, it would remove an objection which may be started on the score of economy, against thorough draining — an objection, however, I believe of no great

weight, if we place, as we should, against the loss by percolation, the gain by active vegetation, kept vigorously so by moisture; and the gain to the soil, through the influence of thorough draining of a decomposing and ameliorating kind, thereby adding to, and deepening and improving it. The solvent power, however, of the percolating water is well worthy of being kept in mind, and it may raise a question of the propriety of applying largely manures to the soil at one time, and whether it would not be better, in the instances of the use of guano, nitrate of soda, and the like, to adopt the method said to be followed by the Peruvians, and make the applications in different stages of the crop, using smaller quantities.

Barbados, in many respects, resembles Malta. I am speaking of them now in their agricultural relations. In Malta, as I have already observed, there is a thin soil, which is of excellent quality, resting on a porous freestone. That island has a regular dry season, extending through the hot months of summer, and sometimes longer. Of water there is a great want. To collect and store it, attention is constantly given, and immense labour has been expended. Not only every house has its tank, quarried in the rock, but also the majority of the fields—fields of terrace-construction called made-fields—"Campi artificiali." When the rains

set in, even the public roads are made water channels, and gutters from them convey the water into the field-tanks, some of which are excavated under the roads, and have mouths usually covered with large stones, even in the roads. When the dry season arrives, these tanks are brought into use. Water is raised from them by the lever and bucket, the simplest of all mechanical contrivances for the purpose, and applied to the watering of certain crops, as the cotton crop at a particular stage, and to various vegetables and fruit-trees. Could such reservoirs of water be introduced into Barbados, they would unquestionably be very useful, especially for the minor crops and for garden cultivation. Of the happy effects of water applied to the latter, an instance offers close to the garrison of St. Ann's, where an intelligent and active Italian from Tuscany has brought a piece of land, recently considered almost worthless, into the highest state of culture; and by the help of water from wells which he has sunk, and which, from their low situation, are never dry, he has succeeded in growing vegetables for the table throughout the year.

I must now, gentlemen, bring this discourse to a conclusion. If I have occupied an undue portion of the time of the meeting, I must plead as an excuse the importance of the subjects treated of, which, even had I more time, I am conscious

I could not have done justice to; and the peculiarity, in relation to the agriculture of the colonies, of the present period, and the prevailing impression, in consequence of this peculiarity, that your agriculture cannot continue to flourish unless all possible means are taken to improve it. I allude to the free-trade measures which have become popular at home, and which have been carried out in part, and are likely to be extended by her Majesty's Government — measures which, if carried out in their true spirit, and liberally and rightly conducted, will assimilate, I cannot help thinking, *international trade* to the *home trade*, now allowed to be the most beneficial and the most profitable. Supposing, then, protection to colonial interests to be withdrawn, as is portended, and no discriminating duties allowed — a form of such protection — you will have to compete with the agriculturists of the world — not only with those of Hindostan and the far East, but what you seem to dread more, with those of Brazil and the Spanish and French slave colonies of the West Indies.

If I may venture to express an opinion, and I trust I may, as it is hopeful, I cannot but think, if you put forth your energies, adopting every improvement that is economical, using implements as much as possible to spare human labour, paying well for what is employed to encourage exer-

tion and skill, and making an effort, which it is to be hoped will have encouragement from the Home Government, to improve your manufacturing processes, — doing this, I cannot but think that you will be successful, and that equally against the very cheap labour of the East Indies, and the slave labour of the West; the one weak and of little efficiency, so that it is rather cheap in name than in reality, and perhaps better fitted for cotton than for the sugar-cane cultivation, to which it appears probable, if the Navigation Laws be abrogated, it will soon be specially directed; the other forced, hardly to be depended on, and as to cheapness and efficiency even doubtful.

We have been told recently, that when the admission of slave-grown sugars into the English market was made known in Cuba, there were rejoicings and illuminations, followed by excessive labour; that the slaves, during crop time, in the boiling-houses, were kept constantly occupied fifteen hours in the twenty-four; and how, in the fields, they were kept to their task by the terror of the whips of the drivers — these defended by blood-hounds; how, in accordance with this system, life is sacrificed there to work, it being thought more profitable to make new purchases, than to take any care, entailing expense, of the labouring slaves, and this, although from 200 to 500 dollars is the market price of a slave. Such

particulars, and others of a horrid kind, we have from a writer, who has recently been in Cuba, he says; and judging from the want of expression of feeling by him in giving the particulars, not averse to slave labour; and therefore, probably, he has not exaggerated.

Such a system—such proceeding may glut the home market for a time; but can it be profitable long? Surely not. A system connected with such monstrous vice, we may be confident, cannot flourish. I should as soon expect that piracy would be successful for a continuance, and become an authorised calling. If it be profitable for the moment, depend upon it it will meet with some great reverse, after the manner of piracy, as exemplified in the history of the buccaniers, and with a punishment equal to the crimes that maintain it. Even without some signal visitation, I cannot believe that such a system can be long profitable, when so high a price is paid for slaves, and the period of their labour is so short, averaging, it is said, not more than ten years. And that it is not, seems to be denoted by these very colonies importing free labourers, and one of them, it is stated, even from China. But whether profitable or not, whether signally punished or not, this we are sure of, that man has a conscience, through which, even in this life, it cannot be doubted that he is punished for his misdeeds, and

rewarded for his good acts. In the ancient drama, the perpetrators of great crimes were held up to horror, as haunted by the avenging furies, lashed by their whips of snakes and scorpions, and allowed no rest. These, in all times, are the stings of conscience when awakened to a sense of guilt.

A President of the United States, Mr. Jefferson, who, from his own experience, knew well the evils of slavery, and the dangers connected with it, alluding to these has said: — "Indeed, I tremble for my country when I reflect that God is just, that his justice cannot sleep for ever; that considering numbers, nature, and natural means only, a revolution in the wheel of fortune, an exchange of situation, is among possible events; that it may become probable by supernatural interference! The Almighty has no attribute which can take side with us in such a contest."

Your success, gentlemen, to which I have said I look forward hopefully, if earned as I expect, will be of the right kind, owing to your own exertions, without any strain on humanity or violation of duty, beneficial to your labourers and the community at large, not likely to be ephemeral, or soon to pass away; on the contrary, to be stable, and to increase in amount with its endurance, — an increase of success that may be held to be characteristic of what is right, of which

we have so many proofs in history, both ancient and modern, and remarkably so, as regards the converse, in the history of our own times, during the last half century, of which that of St. Domingo alone may be held to be an epitome.

These few remarks I trust you will receive with the indulgence I have been accustomed to have from you. They may appear foreign from my subjects; but there are times when it seems a duty to express individual opinion, and to raise the voice against what is monstrous. I have faith that the sentiments I have now expressed will have your approval and sympathy, and so received and approved, individual opinion acquires the character of public opinion, and carries with it its weight.

Apart from virtue and vice, right and wrong, it is a problem, merely economically considered, in the minds of many reflecting persons, which kind of labour is most profitable — slave or free labour. I trust, gentlemen, it is your destiny to prove, and it will be a high destiny in regard to its probable consequences, that the free, the right labour, is truly that which makes, in the long run of time, the best return; and let this be but proved, then, even amongst merely money-making men, slavery should fall, being without even a plausible support.

DISCOURSE V.

ON THE MAKING OF SUGAR AND RUM, THE FORMER SPECIALLY AND GENERALLY CONSIDERED.

Gentlemen,—In addressing you now, I propose to call your attention to two important chemical processes, viz. The Making of Sugar and Rum,—processes in which your interests are mainly concerned, and not only yours, but, I may say, the world's at large; for what civilised country is there in which sugar is not become almost a necessary of life, and how few are the countries, whether civilised or barbarous, in which rum is not used and abused.

On this, as on former occasions when I have had the honour to address you, I shall dwell more on the principles involved in the processes, than on the minute details, either of methods at present in use, or of others proposed for adoption, as improved methods. My doing so is necessary equally as regards the time you can spare to me, and the kind of limited knowledge which I possess of the subjects to be brought under your consideration.

I speak *in limine* thus reservedly of my

knowledge, conscious of the difficulty of the subjects; the partial manner in which my inquiries respecting them have been conducted; and that the majority of my audience are far in advance of me in all that relates to the ordinary methods of manufacture; and that some of you, gentlemen, have studied them with the helps of science.

My chief motive in thus coming forward, is the hope that I may be able to communicate some information; information on particular points, with which you may not be familiar; and to offer some suggestions based on such information, which may prove practically useful. I hope too, that what I shall bring under your notice may excite inquiry; which, should I be so fortunate as to succeed in doing, and even in doing no more, I shall be satisfied; *inquiry*, in my belief, being the first thing necessary, when improvement is aimed at, after conviction that improvement is wanted,—that the processes in use are not perfect.

It may be well, in beginning, to consider what are the contents of the ripe sugar cane. A fresh transverse section of it, a thin slice, is found to be diaphanous, very like a thin slice of an apple or turnip, and homogeneous, as seen by the naked eye. Under the microscope it exhibits a cellular structure, the cells containing a transparent fluid;

there is no appearance of crystals, none of any opaque matter. If the thin slice be dried, the appearance it presents is altered; it is no longer homogeneous as seen with the naked eye or a common magnifying glass; little dots of an opaque whitish matter are visible, protruding, as I believe, from the divided longitudinal tubes, and cells are seen surrounding these opaque dots, cells which are transparent, and in which, placed in sunshine, minute glittering crystals are observable, which, it may be inferred, are crystals of sugar, formed in consequence of the evaporation of the aqueous part of the cell-juice. These observations seem to prove that the saccharine matter of the cane exists in it in a state of solution, according to the commonly received opinion. This I mention particularly, because a different inference has been drawn by some inquirers, viz. that the saccharine matter is secreted in the crystalline state, in brief, as crystals of pure sugar; an inference which, it appears to me, is neither probable, *à priori*, on theoretical ground, considering the strong attraction sugar has for water, nor in agreement with the results of carefully made observation. I may remark, it would be extraordinary indeed if crystals of sugar, a substance which deliquesces in an atmosphere saturated with water, were found to exist in a cellular tissue so

abounding, so saturated with aqueous juice as is that of the cane.*

In the manner in which the cane juice is commonly obtained by the pressure of the mill, it is, as you know, very compounded, both from what it holds in solution and in suspension. However carefully expressed, it is never transparent, it is turbid in a slight degree, and coloured. If viewed under the microscope, with a high power, innumerable granules will be seen floating in the fluid, in diameter varying from ten thousand to fifteen thousand parts of an inch. By filtration through bibulous paper, with care, it may be made transparent, or nearly so; most of these granules are separated. The matter of which they consist, is, I believe, chiefly of the nature of gluten. Like gluten, it has the power of exciting fermentation, as I have ascertained by various experiments made, both on the substance procured by the filtration of the freshly expressed juice, and on some sent me by my friend, Mr. Best, from Blackman's,

* This its powerful attraction for moisture is easily shown by suspending, wrapped in muslin or thin paper, a piece of refined sugar in a bottle (to be well corked) in which there is a little water, in consequence of which the air included becomes saturated with moisture: in this very damp atmosphere, the sugar will be found rapidly to deliquesce, and in a day or two to fall in drops into the water, and continue so to do till the whole of the solid mass disappears.

found adhering to the gutter by which the juice was conveyed from the mill, and which, after having been kept nearly twelve months, still retained the qualities of a ferment.

It is a question to be determined, whether this glutinous matter exists suspended in the juice, as it is contained in the cells, or is separated from the walls of the cells, or from the traversing and broken longitudinal tubes by the pressure employed. I am rather inclined to adopt the latter view, and for this reason, that if the cane be sliced very finely, using a very sharp knife, and water be poured on the slices, a saccharine solution may be procured, as I have found, that is quite transparent, as much so as the most carefully filtered fluid.

Besides gluten, there may be other proximate principles suspended in the fresh juice of the cane. If starch be carefully sought for in the matter separated by filtration, I believe it may always be found. I have never failed to detect it, using iodine as a test, aided by the microscope. But its presence, in the minute quantity in which it occurs, is probably of little importance. And the same remark, I apprehend, is applicable to any other substances which may exist in a concrete form in the juice, such as wax, and especially the woody fibre, consisting of broken portions of the substance of the cane, which may be easily sepa-

rated by sieves of wire gauze of different degrees of fineness of aperture placed between the outlets of the mill and the entrance of the racking copper. The quantity of this is generally considerable; and the more powerful the mill, of course the greater is the proportion of it, and the greater the propriety of removing it, to avoid the effects it may have if subjected to a temperature approaching the boiling point in the process of clarifying the juice. And, in passing, I may remark, this woody fibre, saturated as it is with cane juice, should not be wasted; vinegar may be made from it, if mixed with water and properly exposed to the air; or, it may be given to horses and cattle, to whom it will be acceptable, if put before them previous to the commencement of the acetous change.

Dissolved in the transparent juice, as obtained by filtration, it may be inferred there are several substances, and these varying probably in number with circumstances. Apart from the saccharine ingredients, I am disposed to think that the most important and constant is one that is coagulable by heat, and that at a temperature of about 160 degs. Fahr., in this respect resembling albumen; and having the property of acting as a ferment, in which important quality it also resembles albumen; whilst it differs from albumen in not being precipitated by a solution of corrosive sublimate. When I say that it resembles

albumen, in performing the part of a ferment, I may add, that as in the instance of the *albumen ovi*, the white of the egg, coagulation appears to be essential for the effect to be produced: so long as the cane juice remains transparent, there is no fermentation perceptible; nor is there any perceptible in a mixture of white of egg and a solution of sugar, till a turbidness is produced by the passing of a portion of albumen from the liquid to the solid state. It appears, too, to resemble the white of an egg in another respect. The contents of the egg, so long as they are not mixed together, the white with the yolk, undergo little change, do not become putrid, which they rapidly do when so mixed. I find it is the same with the contents of the cells of the cane; if not broken or bruised, the saccharine juice remains in them many weeks little altered. Here is an example, which has been kept about six weeks, confined merely in a stoppered bottle, and if tasted, the cane will not be found to be perceptibly acid. The same is witnessed in many kinds of fruits, which in consequence, with care to avoid bruising them, may be kept sound for a considerable time. This substance in the cane juice bearing an analogy to albumen, may be considered as belonging to the class of azotised compounds, of which (besides albumen) gluten, curd or caseine, are well known instances, and identical in properties, it would

appear, whether existing in animals or vegetables. Its exact place in this class remains to be determined. Its presence in the juice of the cane is easily demonstrated; and also, that the proportion of it commonly is small in comparison with the glutinous principle. If the fresh juice rendered as clear as possible by filtration be heated to 160 degrees, it becomes slightly turbid, and very slightly. If kept at this temperature some time and then filtered, and afterwards exposed to a higher temperature—if even made to boil, I have not observed it to become again turbid. Whence I am disposed to infer that such a temperature is sufficient, so far as heat alone is concerned, to coagulate the substance under consideration.

Besides this substance, there is proof that there is another, and in some degree an analogous compound, existing in the juice, not separable by heat alone. If the boiled juice, rendered quite clear by filtration, be put aside, in a short time it loses its perfect transparency, it becomes slightly turbid, and air bubbles are disengaged, denoting that it is in a state of fermentation, and that the matter that renders it turbid is acting the part of a ferment. That it does so act is indeed certain, keeping in mind, that a solution of pure sugar in water is not capable of fermenting. A leaven, or ferment, a matter totally different from sugar, and always containing azote, is essential to excite

fermentation. If only the smallest portion of such a matter be added to an aqueous solution of sugar, it will certainly have this effect, at the ordinary temperature of the atmosphere, even in a cool climate. Further, if to the clear filtered juice after boiling, a minute quantity of solution of alum be added and heat be applied to ebullition, a turbidness will be occasioned, and a precipitate on rest formed. After this, I have not found that the juice is liable to ferment; nor have I found that the precipitate is capable of producing fermentation, when added to pure sugar and water.

This matter, of the nature of a ferment, not coagulable by the boiling temperature, I am induced to believe, is not affected by alumine or clay; and I am doubtful whether it is coagulable by lime alone, inasmuch as I have detected it in liquor from the racking copper tempered by means of lime, and tested by litmus paper; but I believe it is coagulated and separable by filtration when, in the process of tempering, lime in excess is used, according to the method recommended by Dr. Shier, neutralising the excess by sulphuric acid; and I believe a similar effect is produced when, as proposed and tried by Dr. Goding, an infusion of tannin is used in the process of clarifying.

This matter, in the operation of sugar-making,

you must be aware is of great importance, inasmuch as it remains in solution after boiling, and has not its power as a ferment destroyed by boiling. I have found it to form the principal proportion of a substance which I received from Mr. Edward Packer, procured by filtering the liquor from the skipping teach, when it was of the temperature 215 deg. of Fahr. It is this substance, it may be inferred, which exists in molasses, and imparts to it its power of fermenting, and exists also, more or less, in all muscovado sugars made by the methods commonly in use, and is the principle chiefly on which their deterioration depends as connected with fermentation, and the changes which take place slowly from the action on each other of the mixed ingredients. I shall revert to this hereafter.

Let us now give our attention to the saccharine matter of the cane juice — that which I have said, even in the cells of the cane, is always in a state of solution by means of water, and which we are certain is so in the expressed juice. It is a question whether this saccharine matter is altogether crystallisable sugar, or in part consists of other varieties of sugar which are not crystallisable, or with difficulty crystallisable. In every trial I have made on the fresh juice, I have detected in it glucose, one of the latter varieties: thus, whenever I have added a little sulphate of copper to it,

and solution of potash sufficient to dissolve the precipitate at first formed, on boiling this mixture an orange precipitate has been obtained, and not a green one or a deep blue solution, which would have resulted had the saccharine matter in the juice been altogether of the readily crystallisable kind: and this is confirmed by the circumstance of the rapid manner in which the freshly expressed juice enters into the vinous fermentation, for which the kind of sugar alluded to, glucose, or grape-sugar, is considered essential. Be this as it may, it is certain, however, that the greater portion of the saccharine matter of the juice is crystallisable, and may be obtained in the state of crystals, if, after *rapid* boiling and filtering for the purpose of clarification, the clear fluid be *rapidly* evaporated. On a small scale the experiment is easily made, and with very satisfactory results, if the juice of canes thoroughly ripe and sound be used. No addition is necessary, not even lime; and the residue not crystallised is small; it is semi-fluid, and almost colourless, and the crystals of sugar are likewise almost colourless. I have laid stress on rapidity of boiling and evaporating, *that* being a condition of great importance in sugar-making, as, by slow boiling, or even exposure for a considerable time to a temperature below the boiling point, glucose may be formed from the purest crystallised sugar dissolved in water. When we

consider how nearly allied these varieties of sugar are, and likewise how nearly allied they are to other substances, such as gum, starch, woody fibre, we cannot be surprised either at the conversion of one kind of sugar into the other or into these substances, or at the formation of sugar from them — changes which are of frequent occurrence in plants during their growth, and are some of them practicable in the laboratory by employing particular methods, and, as you are well aware, are not altogether unknown in the making of sugar; for instance, when the liquor becomes ropy, in consequence of the transition of saccharine into gummy matter — these, substances which are chemically isomeric, that is, identical in composition, so far as their elements are concerned and the proportions of these elements, though the substances gum and sugar are so different in their properties.

In the account just given of the principal constituents of the cane, I have not noticed the fixed earthy or saline matters, such as constitute its ashes, when all that is volatile belonging to it has been dissipated by burning: these matters are chiefly phosphate of lime, carbonate of lime and magnesia, silica, and the vegetable alkali; the greater part of which belongs to the solid portion of the cane stalk and its leaves; the smaller, and that a very inconsiderable part, to the substances contained in the juice dissolved or

suspended. In a former discourse, these fixed matters derived from the soil, as they necessarily are, have been adverted to, and the importance of returning them to the soil, to prevent its exhaustion, insisted on.

I shall now briefly bring under your consideration some of the processes of sugar-making and their products, to which what has been already stated will be more or less applicable as partial tests of the efficiency of the one and of the goodness of the other.

In the most ordinary manner of making sugar, the expressed juice is received as it runs from the mill into the racking copper without the intervention of strainers, is there tempered by the addition of a certain quantity of lime, and, when bubbles of air rise and produce cracks in the adhesive scum — a mixture of gluten, principally, and woody fibre — the liquor underneath the crust of scum, now clear, at the temperature of about 205 deg. Fahr., is drawn off into the boilers, in which, by the action of a strong fire, it is reduced to what is supposed to be a proper consistence for granulation on cooling; a constant skimming going on, a man being stationed at each copper of the set during the boiling, for the purpose of removing impurities that may rise as scum.

If the sugar thus obtained be carefully examined, judging from the trials I have made, it

will, when of the best quality, and after having been well drained of molasses, be found of a grain more or less crystalline; it will be found to lose in drying about 6 per cent., to dissolve in water, leaving but a small portion undissolved, and in this state of solution to be readily fermentable. If examined with the microscope, it will seem to consist of crystals of sugar, and of uncrystallised granules — probably of glucose; of very minute granules not soluble in water—probably an azotised matter, as they are rendered brown by iodine; of starch-particles, also insoluble in water, which are rendered blue by iodine, and of minute fragments of woody fibre.

If of inferior quality, whether owing to the nature of the soil or season, or to want of care in the making, it will be found to abound more in impurities, to give a larger residue when dissolved in water, to sustain a greater loss in being thoroughly dried, and to present more impurities, and fewer well-formed crystals of sugar when seen under the microscope.

An improved method of making sugar is that by the vacuum-pan, and by the so-called Gadesden's pan. I notice them together, because their object is very similar, namely, in the higher concentration of the juice, to avoid the elevated temperature to which it is exposed in the ordinary way, and not allow it in the last stage to reach the boiling point

of water. Another advantage combined with the preceding is the passing of the concentrated juice—concentrated to a certain degree by boiling in the usual way—through a filter, before admitting it into the pan; and a third advantage, I believe, is, that in the pan the concentration is carried farther than it can be with safety in the teach, even beyond incipient granulation.

The sugar thus obtained is purer and more crystalline than ordinary moist muscovado sugar; it consists, indeed, mainly of crystals of sugar slightly coloured, and loses less in being thoroughly dried,—one sample of vacuum-pan sugar which I tried, lost less than 2 per cent., viz. 1·6; it yields only a very minute residue when dissolved in water, and the solution formed is very little prone to fermentation.

It may be well to bear in mind, in connection with these processes, that whatever tends to keep the saccharine matter of the juice unchanged, and to remove impurities, favours the crystallisation of the sugar; and that the formation of well-defined crystals, in its turn, favours the drainage of molasses, and thereby the production of a purer and drier sugar; and I think it not improbable that, under circumstances in which the tendency to crystallise is favoured, even the glucose part may undergo conversion, and become sugar of the first quality.

In illustration of these remarks may be mentioned the excellent quality of vacuum-pan sugar obtained on the Lemon Arbor estate, in this island, the property of Mr. Maycock, mainly owing, I believe, to two peculiarities of treatment adopted by that enterprising and intelligent gentleman; one, allowing the liquor (the cane-juice), after having been clarified and skimmed, and reduced by boiling to 24 deg. of Baume's hydrometer, to remain at rest in a cistern for twenty-four hours, when a considerable sediment of the matter of ferment takes place; the other, potting before the liquor is reduced to a high degree of concentration in the vacuum-pan, and leaving it undisturbed to crystallise in the vessels to which it is transferred — the best form for which seems to be the conical — when a farther separation of leaven takes place, rising to the surface, as a grey scum.*

A process has been employed by Dr. Shier, already alluded to, recommended by its simplicity, and I believe I may add efficacy, and is, in consequence, as might be expected, considering who is its author, very deserving of attention. It consists in tempering with excess of lime, filtering after having brought to ebullition the tempered juice, — an operation (that of filtering) which the excess of lime appears to facilitate,—and neutralising that excess by sulphuric acid. After this, the

* See Agricultural Reporter, vol. iv. p. 171.

reduction of the liquor to a proper state of concentration for skipping is conducted without any skimming being required; and the skipping—the transfer of the concentrated liquor—is made at a high temperature, viz. between 238 deg. and 240 deg. Fahr.

The sugar thus obtained, it would appear, has most of the good qualities of the vacuum-pan sugar. It is not, indeed, so highly crystalline, but it is, judging from the specimens I have seen, of as light a colour, as little disposed to ferment when dissolved in water, and yielding when dissolved as small a residue. According to the trials made by Dr. Shier, it loses in drying from 3 to 5 per cent.; and it is in its dried state that it is exported. The samples of sugar thus made, which have been sent to England, I am informed, have been priced by the brokers at 6*s.* the cwt. above the ordinary sugar of Demerara. One great advantage of this process of making sugar is, that the ordinary implements of the boiling-house are the only ones required, and that no additional cost is entailed—the expense of the sulphuric acid used being so trifling, that it may be left entirely out of the account,—and no increase, but a diminution of labour, and also a diminution of waste in consequence of skimming not being necessary.

The results of this method really appear to me to exceed greatly what might *à priori* be expected

from it. I apprehend the addition of the sulphuric acid is beneficial, not only in neutralising the lime in excess, and in decomposing any compound of lime and sugar formed, but also in other ways. It may tend to convert starch into sugar. We know that when starch is boiled in water, slightly acidulated with sulphuric acid, it is so converted; but to this I attach little importance. It may expel any acetic acid present in combination, or any carbonic acid, converting any acetates which may be in the liquor, or carbonates, or even nitrates into sulphates — a conversion, I believe, not unimportant, for, according to some trials which I have made, (it has been in the instance of curd, and I mention the results only incidentally,) curd may be kept many months in a solution of sulphate of soda, or of sulphate of magnesia, apparently unaltered, not discoloured, whilst in a solution of carbonate of soda, or potash, or ammonia, or of nitrate of potash, it undergoes material change, and becomes of a dark brown. By analogy, it may be conjectured that, in the process of sugar-making, the presence of any alkaline sulphates formed may be equally innocuous on the very little azotised matter, if any, remaining, and may tend to render it inert as a ferment.

Another advantage may be mentioned connected with this process, which is deserving of attention, viz. the high striking temperature — a temperature

which, in this instance, contrary to what might be expected, does not appear to have any injurious effect on the quality of the sugar. The power water possesses of dissolving sugar, is, in a great measure, proportional to its temperature; a saturated syrup made with boiling water, contains in solution about five parts of sugar; made with cold water, it contains only three parts; and, consequently, in the cooling of the former, two parts merely will be deposited from the difference of temperature, and the greater that difference, the more sugar will be deposited in the cooling; and hence, obviously, *cæteris paribus*, the advantage of skipping at a high temperature. On this effect of change of temperature, the whole process of sugar-making by the ordinary methods may be said to depend — a fact, perhaps, not sufficiently regarded, too often wastefully overlooked; it is too often forgotten that, by subjecting the molasses to a second boiling, or by returning it to the clarifier to be mixed with fresh juice, an additional quantity, a large increase of sugar, may be obtained.

Excellent muscovado sugar, I understand, is made in Vera Cruz, said to be the best in the West Indies. From what I have heard of this process, it is very simple, its peculiarity being chiefly in the method of clarifying. This is effected by the substitution of steam-heat for that

of an open fire, applied to the racking copper; filling this vessel, which is of a square form, to the brim; raising the temperature of the juice to about 120 deg.; and then separating the scum that rises, by passing a long flat piece of wood over the surface. The tempering follows; it is effected at 180 deg. Fah., with milk of lime passed through a fine wire-gauze filter; and the second scum, that which rises after this addition, is removed in the same manner as the first. Finally, before boiling the liquor is filtered.

These improved methods, and others which might be mentioned, have naturally resulted from competition, and the comparatively low price of sugar, mainly the consequence of that competition, augmenting the quantity produced more rapidly than the demand increased. In every branch of industry we may be sure that intelligent and prudent enterprise will be remunerated, and that old and imperfect methods, invented when the prices of sugar were high, in consequence of the demand exceeding the supply, cannot be successful now, as then; and that the planter will be blind to his own interest, and be carrying on a losing concern, if he do not avail himself of methods found by experience to be superior to the old, and more profitable — the business-test of that superiority.

The making of sugar has owed much to science.

It was a philosophical chemist (the same who first analysed meteoric stones, and proved them to be meteoric,) who introduced the vacuum-pan method into use, by which such facility was given, with a remarkable reduction of the price of the article, to the refining of sugar. In France, it has been by the application of chemical science that beet-sugar, the produce of the country, has been able to compete with cane-sugar, affording a remarkable instance of a conquest, I may say, and triumph effected by science, the proportion of saccharine juice in the beet-root being only about half as much as in the cane, and mixed with substances more difficult of extraction and more injurious in their reaction. Let the same skill directed by science, be applied to the making of sugar from the cane, and we may reasonably expect the happiest results. And that there is ground for such anticipation seems to be proved by what has been ascertained by the analysis of the fresh cane. In its ripe state, it would appear to contain, on an average, about 17 per cent. of sugar dissolved in 73 of water, the woody fibre, the receptacle, being about 10 per cent. No allowance in this estimate is made for the other ingredients, because they are in so minute a quantity. In comparison, how small is the proportion of sugar actually obtained by the planter! Instead of nearly 17 per cent., it would appear to

vary from 3 to 8 per cent. In Louisiana, where the canes are seldom fully ripe, it is said that hardly 3 per cent. of sugar is obtained, *i. e.* from 100 lbs. of cane, and that with difficulty. In Cuba and Porto Rico, the produce is increased to 4 per cent.; in the French and British colonies to about 5; and by Dr. Shier's method, we are informed by him, the produce has varied from 7·3 to 8·1 per cent. These differences, and the produce being so low, compared with the quantity of saccharine matter in the juice, are chiefly owing, there can be little doubt, to the manufacturing methods in use, and to the kind of, and often imperfect, mill-power employed to express the juice, ordinary mills expressing little more than 50 per cent., whilst steam-mills of the best construction are capable of expressing 71 per cent., sacrificing the megass, which, by this great pressure, unless the action be proportionally retarded, is too much broken to be used as fuel, and 65 per cent. without injury to this article as fuel. When we reflect on these circumstances, how manifest is it that there is a great opening for economical and profitable improvement in the making of sugar by the application of science, chemical and mechanical, to the process.

With your permission, I shall now call your attention to another branch of our subject, not unimportant or uninteresting in an economical

point of view, both in relation to the interests of the planter and the consumer, viz. the state in which it is most advantageous to have sugar manufactured for the market, and especially for exportation; and the quality or kind of sugar which is most wholesome, most nutritive, and, consequently, best fitted for general use as an article of diet.

As regards the nutritive power of sugar, we are sure that it is not the pure kind, that which is doubly refined, that is most nourishing. It contains no azotised matter, no phosphate of lime; and, consequently, neither the growth of the young, nor the waste of the animal structure in advanced life, can in the one instance be maintained, or in the other restored by means of it. Dogs that have been fed on pure sugar, have rapidly died from inanition. All muscovado sugars contain a certain portion of azotised matter, and these, consequently, must be considered as most nourishing; and, probably, the higher in degree, the larger the proportion of this matter. Such is the conclusion, reasoning on the subject *à priori;* and the correctness of it seems to be confirmed by several facts besides the one already mentioned. During crop time, when the fresh juice of the cane is so profusely used, all animals, and not least the labourers, improve in condition. The negro prefers muscovado sugar to refined sugar for his own

use. Ants show the same preference: if allowed access to syrup exposed to the air,—its aqueous part, in consequence, slowly evaporating,—I have observed, after a time, a residue of white sugar, the ants having carried off the browner particles and any adhering molasses.

In the instance of refining sugar, I believe a fastidious, and perhaps an acquired taste has been consulted rather than health; it having been used at first as a luxury, only gradually become, as it now is, a necessary. If this be true, as I believe it to be, it would be well to keep it in mind, and to act on it in some measure, both in the conducting of the manufacturing process, and in the selection of the article for domestic use.

As regards the state in which sugar should be prepared for exportation, I apprehend that, with a view to economy, both to diminish the cost of freight and to avoid the loss by leakage, whatever the qualities of the muscovado sugars may be, they should be thoroughly dried in the first instance; an operation which, if properly conducted, is neither difficult nor expensive. From 2 to 6 per cent. of water being expelled in the drying, the freight will be so much the less; and not only will all leakage be prevented, but all fermentation, and this even in sugars of least purity, such as contain most ferment, water being essential to the fermenting process; and, likewise, it is pro-

bable that all deteriorating change will be prevented, the result of the action of the impurities on each other and on the sugar, moisture being necessary to promote such a change. Thoroughly dried sugar may be compared to thoroughly dried fruits, which will keep for almost an indefinite time if preserved in that state; and, like fruits, are prone to a certain kind of decay if not so dried, or if moisture be admitted to them. Dried sugar too, like fruits, can be packed in baskets, and so exported; which, in many situations, may be an advantage in point of economy and facility of transport.

These remarks, in great part, apply also to molasses. If dilute, it readily enters into fermentation, occasioning often a great loss; a change which may be checked by concentration; but whether entirely prevented without carrying the concentration to inspissation, I am not prepared to say. This is a question that can be determined only by experiment; as is also the question whether the concentration of the molasses, or its evaporation to dryness, may not in some instances be advisable, when it would be converted into an article not differing much from the coarse sugar— the jaggery of India, so much used by the natives. As regards the strength of molasses, it should be remembered, that it is capable of absorbing water from moist air, as well as of losing

water when exposed to dry air, and especially to a strong current of air. Too frequently, I believe, it is kept, before being put into casks, so situated as to be likely to become more dilute rather than more concentrated; and, from being only partially covered, to become more impure, from dust and insects falling into it.

The making of rum, to which I now beg leave briefly to call your attention, being, in all its parts, strictly a chemical process, success in the operation must necessarily very much depend on its being conducted in a scientific manner, or according to the principles determined by chemical research. The result to be obtained is the conversion of a saccharine into a spirituous and volatile fluid; in brief, the production of alcohol from sugar. The elements concerned are saccharine matter, leaven, or a matter of ferment, and water. The conditions required are a certain degree of dilution, a certain temperature, and the exclusion, as much as possible, after the fermentation has commenced, of atmospheric air. The success of the process is determined by the knowledge of the proportions in which the several ingredients should be mixed, and in the observance of the circumstances favourable to fermentation; and also in the knowledge of the exact time when the fermenting process is concluded, and when that of distillation should be entered upon:

for if there be loss of time, any considerable interval between the completion of the one and the beginning of the other, loss of spirit will be sustained, inasmuch as in the fermented fluid, leaven being present, the tendency, through the influence of that leaven, if atmospheric air be not entirely excluded, is to the conversion of the spirit into vinegar. In the change of sugar into alcohol, and of alcohol into vinegar, there is a new arrangement and proportioning of the constituent elements. Carbon, oxygen, hydrogen, are the constituents of each. Sugar differs from alcohol in containing more carbon and oxygen. Alcohol differs from vinegar in containing less oxygen and more hydrogen. In the process of the spirituous fermentation, carbonic acid is disengaged, thereby removing a certain portion of carbon and oxygen. In the process of the acetous fermentation (strictly a process of oxidation, and not one of fermentation) a certain quantity of oxygen is absorbed, thereby increasing the proportion of this element, with a diminution of the hydrogen element.

To insure a steady and active fermentation, the most important circumstance is the addition of ferment in sufficient quantity. The scum from the racking copper and the skimmings are more than sufficient for the purpose, when the processes of making sugar and rum are carried on at the same time; but, as it more commonly happens

that rum is made after the sugar, and from molasses alone, there is often a deficiency of ferment, and, in consequence, the operation of fermentation proceeds languidly, and vinegar is formed as well as spirit. To be provided against this, and to avoid the expense of importing yeast from England, it may be advantageous to have in store a good quantity of the sugar-ferment, viz. the scum from the racking-copper and the skimmings, either preserved by being dried, or by being put aside and kept as much as possible excluded from the atmosphere. The former I believe is most practicable. According to the trials I have made, this ferment retains its virtues, so preserved, for many months. It is well to bear in mind, that the ferment is very little wasted in the operation, that no part of it enters into the composition of the spirit formed—it acting mainly, if not altogother, as a stimulant or exciting body on the elements of the sugar, promoting the new arrangement which takes place of the elements essential to the conversion into alcohol; acting, briefly, in a manner not unlike that of a spark of fire on gunpowder, or that of a high temperature, such as flame possesses, on oil or wax in exciting combustion.

Another circumstance of importance is the proper dilution of the liquor to be fermented, to be determined by its specific gravity. If too much water be added, the fermentation will be

feeble, the operation protracted, and imperfect in its results, and much fuel will be consumed in the process of distillation ; if too little water be added, there will be a waste of saccharine matter,—the spirit formed in the fermenting vat will check further fermentation, and the conversion of the saccharine matter into spirit.

Scrupulous attention to cleanliness in all parts of the process, cannot, I believe, be too much insisted on. If the vessels are impure, if any acid, such as vinegar, adheres to them, or any mouldiness, the tendency will be to the conversion of a part of the saccharine matter into vinegar and into mucor. It is considered a proper precaution to wash out the vats with lime water; and it would probably be useful to add some carbonate of lime in powder, such as prepared chalk, or calcareous marl, to the liquor and to the ferment, for the purpose of neutralising the acetic acid that may have formed in them.

On the process of distillation I shall not attempt to offer any remarks, not having given it, as it is conducted here, specially my attention; and entertaining the hope that, ere long, as the sugar-manufacturing processes are improved, with increased profits, it will be for the interests of the planter, as it will unquestionably be for the interest of mankind, to make more sugar and less rum, and that smaller quantity of superior

quality, so as to be of higher price, less easily obtainable, and less unwholesome. Dr. Mitchell, of Trinidad, has lately proposed an ingenious method of making sugar, and, as he thinks, of superior quality, and at a cheap rate, viz. from the juice obtained from the canes, after having been subjected, before expression, to the boiling temperature. If this method should be found successful, as the greater part of the gluten and azotised matters would be retained in the cellular tissue of the canes, coagulated by the heat, little scum or matter of ferment would be thrown up in the operation of clarifying; and, consequently, the process would be very unfavourable to the making of rum: thus affording an instance in point.

I believe, to express frankly what I think, it would be well for mankind if such a spirit as rum were unknown, the deleterious effects of which, when abused, have been so fatal to the health of the white inhabitants of these colonies, keeping down the population, and creating a reasonable and serious objection to European immigration. One great evil, that of slavery, has happily been removed from hence. It is not, surely, a false feeling of humanity to desire the putting a stop to perhaps the next in point of magnitude, regarding its consequences, viz. the use — the abuse of rum — for they can hardly be separated. Were white labourers temperate, I have little doubt

they would be able to bear the climate of the West Indies infinitely better than they have hitherto done, and that they would have a greatly better chance of escaping most of the fatal diseases peculiar to the climate; and, what is worse than bodily disease, that degeneration to which they are subject from the influence of intemperate habits and of climate combined — a degeneration of which there are too many and melancholy instances in this island, in the descendants of the original white colonists belonging to the class of labourers. With these, it is deserving of remark, are strongly contrasted men of the same race as regards aboriginal stock, the gentlemen, planters who, though very much exposed to the open air and to the sun, and taking very much exercise, yet commonly enjoy good health, and rarely suffer from those diseases of climate alluded to above.

Situated as these colonies are at present, competing with the Spanish and Portuguese colonies in the culture of tropical produce, is it not most desirable that their free population should have all the advantages that may be reasonably expected to be attainable where there is freedom? advantages arising out of a superior moral and religious education, and also from a scientific education, ensuring better conduct, greater industry and skilled labour, and that highest kind of skilled

labour which is hardly attainable without a knowledge of the principles of science? To what does the mother country owe her superiority? Is it not to the knowledge, to the skilled scientific labour alluded to? We witness it in the steam-engine in its innumerable applications, which never could have been perfected without the thorough understanding of a principle in connexion with latent heat, which, at first view, would seem to have no relation whatever to the production of mechanical power. We witness the same in the chemical processes of manufacture, so various and important — varying from the making of glass, which, when properly shaped and adjusted, constitutes those admirable instruments, the telescope and microscope, to the reduction and casting of metals, whether to be employed in the printing type, that great organ of literature and mental power, or in the formidable engines of war, the protecting, and, it is to be hoped, as such, the furthering means of advanced civilisation and of civil liberty.

I refer thus to skilled labour and its results, in connexion with science, because I am apprehensive that in many minds in the colonies there is a tendency to underrate the power and advantages of science, arising, perhaps, out of either an imperfect idea or vague notions of what true science is, viz. a system of exact knowledge—in mecha-

nics constituting mechanical science; in chemistry, chemical science; in agriculture, agricultural science;—its exactness determining its value and power in relation to its application to the arts. Thus, that artist who understands thoroughly the principles of the steam-engine and of the vacuum-pan is best qualified to superintend the erection of either, and their repair when out of order: he will have no difficulties to encounter; he will be liable to make no mistakes. He will not have the worm of a vacuum-pan removed to ensure its safety from explosion, as I know has been done by an engineer unacquainted, it may be presumed, with the principles of the apparatus he was highly paid to have charge of. Thus, again, that sugar-boiler who possesses sound chemical knowledge, and who has made himself acquainted with the composition and properties of the juice of the cane, is best qualified to conduct the process of sugar-making, and to engage in research for its improvement. In such inquiry, he will not make experiments, as it were, in the dark, and at random, but, knowing the elements he has to deal with, all the trials he may institute will be made with a definite object in view, and in an orderly manner. He will not, as we know has been done, for the purpose of clarifying the liquor, add to it the ashes of the cane, introducing thereby substances which, if previously present, it would be desirable to have

removed, being of injurious quality, such as the saline portion of these ashes. Much less will he consider himself under a spell — bewitched — should the produce of sugar at any time be smaller than usual, an impression, we are told by Baron von Humboldt, not unfrequently experienced and expressed by the slave sugar-boiler in Cuba.

To recur to the advantages of education such as I have alluded to:—The abolition of slavery is not in itself sufficient either to ensure the welfare of the emancipated class, or of the population generally; of which, in the social system, they form so considerable a part. The uneducated free man is a savage, and, may we not say, of the lowest kind? Liberty not understood, unrestricted by law, is not deserving of the name. In St. Domingo we have proof of this, in the low and degraded state, morally and intellectually considered, of its coloured population. In our own colonies we have proof, though, happily, in a less degree, of the evils resulting from the want of proper training of the minds of a large portion of the same class of persons, in their dissolute and licentious manners, and addiction to vice productive of crime. Should not then the most strenuous exertions be made to educate the people, on the certainty that it is dangerous to leave them uneducated, and that no considerable prosperity

can be attained unless the great majority of them are rendered worthy of it, by means of a sound education — a mean also of arriving at that prosperity — in which attention shall be directed, at the same time, to morals, religion, and secular knowledge, proportioned, especially the last, to the wants of the individuals in their several grades?

Your attention, gentlemen, will presently be called, by the Provisional Committee of the School of Practical Chemistry, now under the auspices of His Excellency Governor Reid, about to be opened, to that institution.* Let me express the hope, that it will have your support; that, ere long, it will be in active operation, and be a demonstrative example of the benefits which science, in its practical application, is capable of conferring. Should it succeed, having commenced at a period of peculiar difficulties, how encouraging it will be to attempt something more considerable, less limited — such, for instance, as a college for instruction in the sciences generally, especially medicine, in connection with your civil hospital, — a college in which the youth of these islands may be enabled to receive an education qualifying them, not only for those commonly called the learned professions, but for all others requiring for successful prosecu-

* June 24. 1848. See p. xi. Introduction.

tion the aids of science, especially agriculture, and qualifying those of the African race philanthropically disposed to become missionaries in their aboriginal country, and to introduce into Africa, at the same time, the humanising influences of religion and science.

Plans, I perceive, are at the present moment benevolently proposed for establishing colonies from the West Indies on the coast of Africa, with a view to its civilisation. Do not let us forget the interests of the two countries—what is most wanted in the West Indies, what is most wanted in Africa, viz. labourers in the one, and instruction in the other. Should not then the principle be to augment the population in the West Indies by immigration from Africa; and, in return, to supply to Africa missionaries of its own race, fitted by constitution to bear the climate, and competent by education given here to engage in the noble attempts directed to the civilisation of their countrymen on their own shores? Could this be accomplished, then indeed a beginning of compensation would be made to Africa for the miseries brought on that unfortunate country by the slave trade, and a well-grounded hope might be entertained how gradually that wicked and cruel trade may be abolished, and that entirely, throughout the world.

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